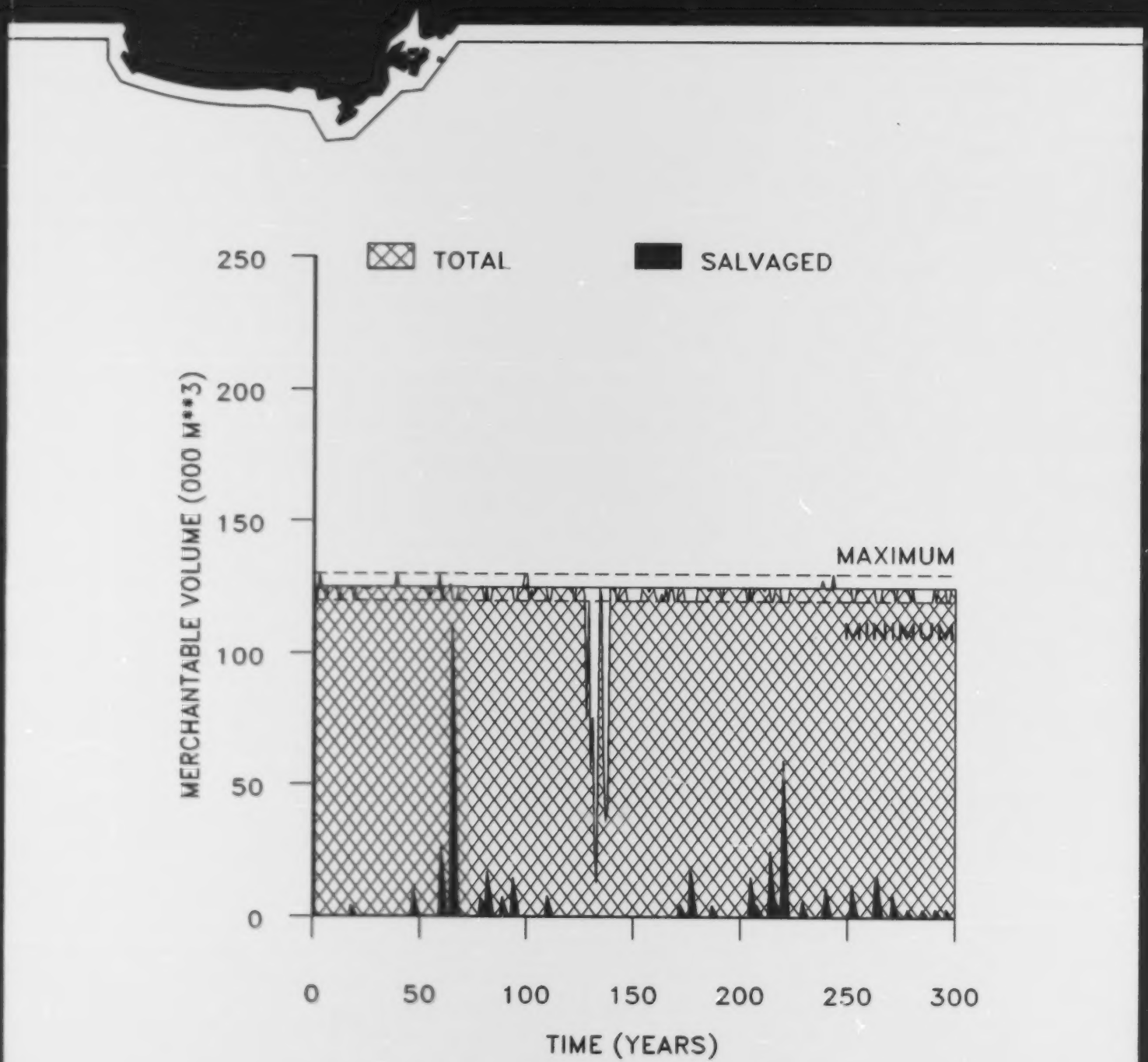
FIRFOR — A simple forest management model



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FIRFOR - A Simple Forest Management Model

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ABSTRACT

FIRFOR is a forest management simulation model that is envisioned to be part of a comprehensive decision support system to aid forest managers in seeking the best solutions to everyday problems. Although in its early stages of development, FIRFOR can provide valuable insight into the long-term effects on yield of forest fire under a number of different management strategies. The area burnt each year may be constant or, more realistically, can be drawn at random from a known Weibull distribution whose parameters are set by the user. Forest management options are confined to the method of selecting stands for harvesting. These include selecting according to stand age, stand volume, or rate of growth. The annual harvest may be controlled by area (with a volume check) or by volume (with an area check). A proportion of the wood that is burnt in any year may be salvaged during the subsequent 1 - 4 years. At present the forest may consist of only one forest type (with 1 - 3 site classes). It is expected that the model will be refined so that several forest types may be considered, the basic data for each of which would be compiled from the geographic information system for a forest management unit.

RÉSUMÉ

FIRFOR est un modèle de simulation de l'aménagement forestier, conçu pour faire partie d'un vaste système d'aide à la décision destiné à faciliter aux gestionnaires forestiers la recherche des meilleures solutions aux problèmes habituels. Même s'il est à ses premiers stades de développement, FIRFOR peut donner un aperçu utile des effets à long terme de nombreuses stratégies d'aménagement sur le rendement forestier, suite à un incendie. On peut supposer que les superficies incendiées chaque année sont constantes ou, de façon plus réaliste, qu'elles sont aléatoires et les établir à partir d'une distribution connue de Weibull dont les paramètres sont fixés par l'utilisateur. Les options d'aménagement forestier sont limitées à la méthode de détermination des peuplements où se fera la récolte. Les possibilités comprennent le choix des peuplements en fonction de leur âge, de leur volume ou de leur vitesse de croissance. La récolte annuelle peut être déterminée en superficie (avec vérification du volume) ou en volume (avec vérification de la superficie). Une proportion du bois qui est brûlé en une année peut être récupérée de un à quatre ans après. Actuellement, la forêt considérée ne peut être constituée que d'un type de peuplement (avec un à trois classes de site). Il est prévu que le modèle sera perfectionné de façon à permettre de considérer plusieurs types de peuplements, les données de base pour chacun seraient extraites du système d'information géographique pour une unité d'aménagement forestier.

FIRFOR - A SIMPLE FOREST MANAGEMENT MODEL

INTRODUCTION

The Forest Management Systems Program at the Petawawa National Forestry Institute was established in 1985 with one of its main objectives to develop a comprehensive decision support system (DSS) for forest managers. Such a system would take advantage of recent advances in information technology, such as data-base management (DBM), geographic information systems (GIS), and artificial intelligence (AI), to provide the practising forester with an easy-to-use tool for testing different management strategies to help resolve everyday problems.

The ultimate system would consist of a series of models that would interface and interact with one another. The components could consist of models of growth or stand development, forest fire prediction and management, pest management, forest management, silviculture, harvest scheduling, road network and location, wildlife management, and probably others, some not yet even considered by today's foresters. In some areas, particularly growth and yield and forest management, many models exist already. Some of these have narrow applications while others are broadly based.

In the general area of forest management models, there are two main types: optimization models and simulation models. Optimization models, as their name implies, maximize production or profits, or minimize costs for a given set of conditions and constraints. They use accepted and well documented mathematical methods (e.g. linear, integer, and dynamic programming) although the preliminary work to prepare data for analysis by these methods (and afterwards the interpretation of results) may be complicated. One of the first such models, and one that is still widely used in various modified forms, was Timber RAM (Navon 1971, Johnson et al. 1977, Armstrong et al. 1984). Newnham (1975, 1976) also used linear programming to optimize logging plans. Dynamic programming was used by Brodie and Haight (1985) to optimize silvicultural investment for several stand projection systems, and by Tait (1986) to determine optimum financial rotations in coppice stands. Such optimization models may be subject to misuse (Chappelle et al. 1976), particularly by unsuspecting foresters who treat the computer as a "black box" that will provide solutions to their planning problems at the press of a button. To provide solutions to the complex problems that are encountered in real life the models may require considerable expensive CPU time on a mainframe computer (with the advent of "super micros" in the near future this may not be a disadvantage for much longer). They may be inflexible and difficult to adapt or modify to changing conditions.

Simulation models are not designed to provide an optimal solution to a planning problem, although output from several simulation runs may be used as input to an optimizing program. Rather, they are designed to answer "what if" questions (Marshall 1986): what effect will a 10 per cent increase in mill demand have on long term timber supply or, what happens to timber supply

if a fire destroys 20 per cent of the forest management unit? (It should, in fairness, be noted that optimization models can be used to answer such questions by simply changing some of the constraints and re-running the program). Simulation has been widely used in stand modelling for a number of years (Newnham 1964, Bella 1971, Arney 1972, 1985, Ek and Monserud 1974, Hegyi 1974). Most of these models project the growth of the individual trees in a stand by taking into account the amount of competition to which they are subjected. In this way it is possible to project the growth of the complete stand under different conditions of spacing, thinning, mortality, etc. Until more information from managed stands and plantations becomes available, these models are often the best that are available for managed stand growth projection. The STEMS model (Belcher 1981, Belcher et al. 1982, Miner and Walters 1984) is currently one of the most widely applied growth models. An example of a forest management simulation model is WOSFOP (Hall 1977) that is used in New Brunswick (and, with modifications, in Ontario) for forecasting timber supply according to different management strategies and sets of rules. This, and similar models, although based on simple principles, can become quite complex as more and more factors are taken into consideration. Van Wagner (1983), on the other hand, used a relatively simple simulation model to demonstrate the effect of forest fire (a factor previously ignored in wood supply models) on long-term, equilibrium timber supply. Reed and Errico (1985) used graphical methods to study the same problem and achieved results similar to those of Van Wagner.

Most models, whether they be for optimization or simulation, are adequately documented from the standpoint of a potential user but their "inner workings" are rather poorly documented. The reasons for this are plain: there are many potential users who, providing that they are satisfied with the results produced by the model, have no need to know the details of how the model works or the program code. Only the "expert" - the person who wishes to modify the model - needs this information and to obtain it he has to examine the program code. This can be a painstaking task and it is often more efficient to rewrite the computer programs, as has been done in developing FIRFOR.

The objective of the simulation model, FIRFOR, is to provide a framework on which will be built the future modelling efforts of the Forest Management Systems Project. It is unique in that it takes into account the considerable variation in annual area burnt and its consequent effect on annual harvest under different forest management strategies. Certain other options are available; for example, fire-damaged wood may be salvaged in the years following a fire, or the degree of "compliance" with the specified management rules may be simulated. Given the probability distribution for the annual area burnt, the forest management option, and the various constraints on harvesting, the model predicts the annual harvest, the proportion of the annual harvest that is from fire-damaged wood, and the age classes within each site class that should be harvested each year. Track is also kept of growth and depletion, forest inventory, and age-class distribution. Although not an optimization model, by undertaking a number of tests with different management strategies FIRFOR can aid the forest manager in selecting the best strategy for given operating conditions. At present, because of the assumptions that have been made with respect to the data and functions that drive the model, only "trends" can be predicted. Nevertheless, such trends can sometimes be

revealing. Predictions in real terms can only come about when the input data and functions have been refined.

DATA

The Forest

For the present series of tests, a forest area of 100 000 ha has been assumed. This is a fairly typical size for a Forest Management Unit in Canada (see, for example, Armstrong et al. 1985) and one that is normally expected to supply the mill furnish for a company's manufacturing facilities located in the area. The basic forest is assumed to have only one species type, black spruce (Picea mariana (Mill.) B.S.P.), with a uniform age-class distribution, each age class containing 50 per cent of site class 2, and 25 per cent each of site classes 1 and 3*. Thus the structure of the forest could hardly be more simple.

Yield Function

Plonski's yield tables (Plonski 1974) were "formulated" to predict growth and yield in the model. To obtain a satisfactory fit to the tabular values, a complex polynomial regression equation was developed. For black spruce

$$VM = 265.8 + 3.381A + 0.7876AS - 0.3519 \times 10^{-6}A^4 + 156.4S - 319.4\ell nS - 0.4719AS^2 + 0.001176A^2S^2 \quad [1]$$

where Vm is the merchantable volume in m^3/ha, A the age in years, and S the site class (1, 2, or 3). Negative estimates of Vm are set equal to 0. Within the age range of the tables (0 to 150 years), this equation gives estimates that seldom differ from the tabular values by more than 2 m^3/ha. The polynomial equations were preferred to the nonlinear equations used by, for example, Payandeh (1974) as the latter are asymptotic, i.e. they reach a maximum value beyond which there is no decline in stand volume. It is generally accepted that, if stands are not treated, they will eventually start to break up and decline in volume. If equation [1] is extended beyond 150 years, it can be seen from Figure 1 that Vm does decline for all three site classes, eventually diminishing to 0 between 200 and 225 years. Although unsupported by the yield table data, this volume decline is thought to be realistic. In any case, any errors in volume estimates above 150 years will not seriously affect the results obtained from FIRFOR as, in the managed forest, it is unlikely that any stands would remain unharvested beyond 150 years. The model assumed that, once a stand had been harvested, destroyed by by fire, or declined to 0 volume, it would be regenerated without delay and the yield cycle would recommence.

In practice, it is anticipated that less complex equations than [1] would be used in the model and that, within a region, these equations would have a common form regardless of species or stand type. The user would then be required only to enter the correct coefficients. Alternatively, a "table look-up" method could be employed.

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*The current version of FIRFOR is also able to simulate the development of a forest of red pine (Pinus resinosa Ait.), a species with a considerably higher yield than black spruce.

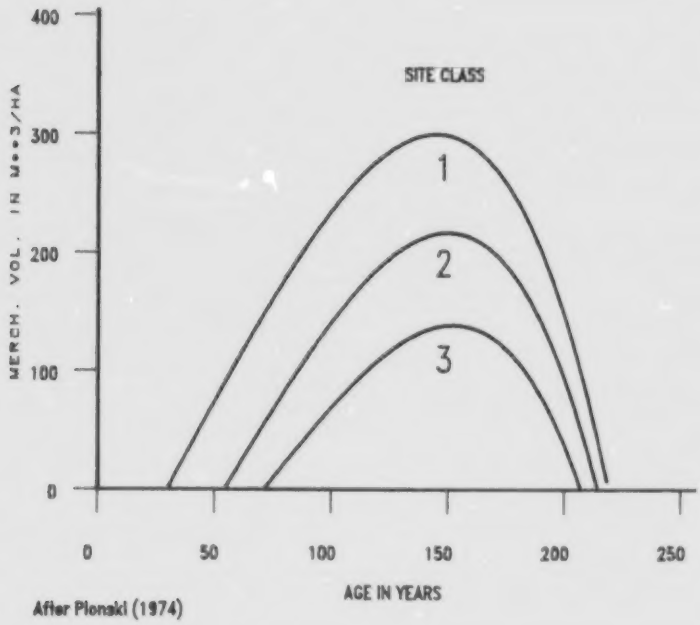

Figure 1. Yield curves for black spruce

Fire Prediction

FIRFOR uses two functions to simulate the area of forest that is destroyed by fire each year.

The first of these is a Weibull distribution function of the form:

$$F_X(x) = 1-e^{-(x/b)^c}$$

where x = the proportion of the total area that is burnt in any year, and b and c are parameters ($b > 0$, $c > 0$). To generate the area to be burnt in any year during a simulation run, a proportion is drawn at random from this distribution using the formula:

$$x = b[-\ell n)1 - R_n)]$$

where R_n is a random number from an uniform distribution ($0 < R_n < 1$). For testing the FIRFOR model, values of b = 0.001 and c = 0.35 were used. The theoretical distribution for these parameter values, and for five other distributions with the same mean but different values of b and c, are shown in Figure 2. On the average approximately 0.5 per cent of the area was burnt each year but, on one occasion during the 300-year period, 25 per cent of the area was burnt. Fires of 25 000 ha do occur from time to time so that this "disaster" is not entirely unexpected. The values of b and c would vary with the area of the forest unit: larger areas would have a smaller range in the proportions of the area burnt each year while smaller areas would have a greater range (in an extreme case, the range could be from 0 to 100 per cent,

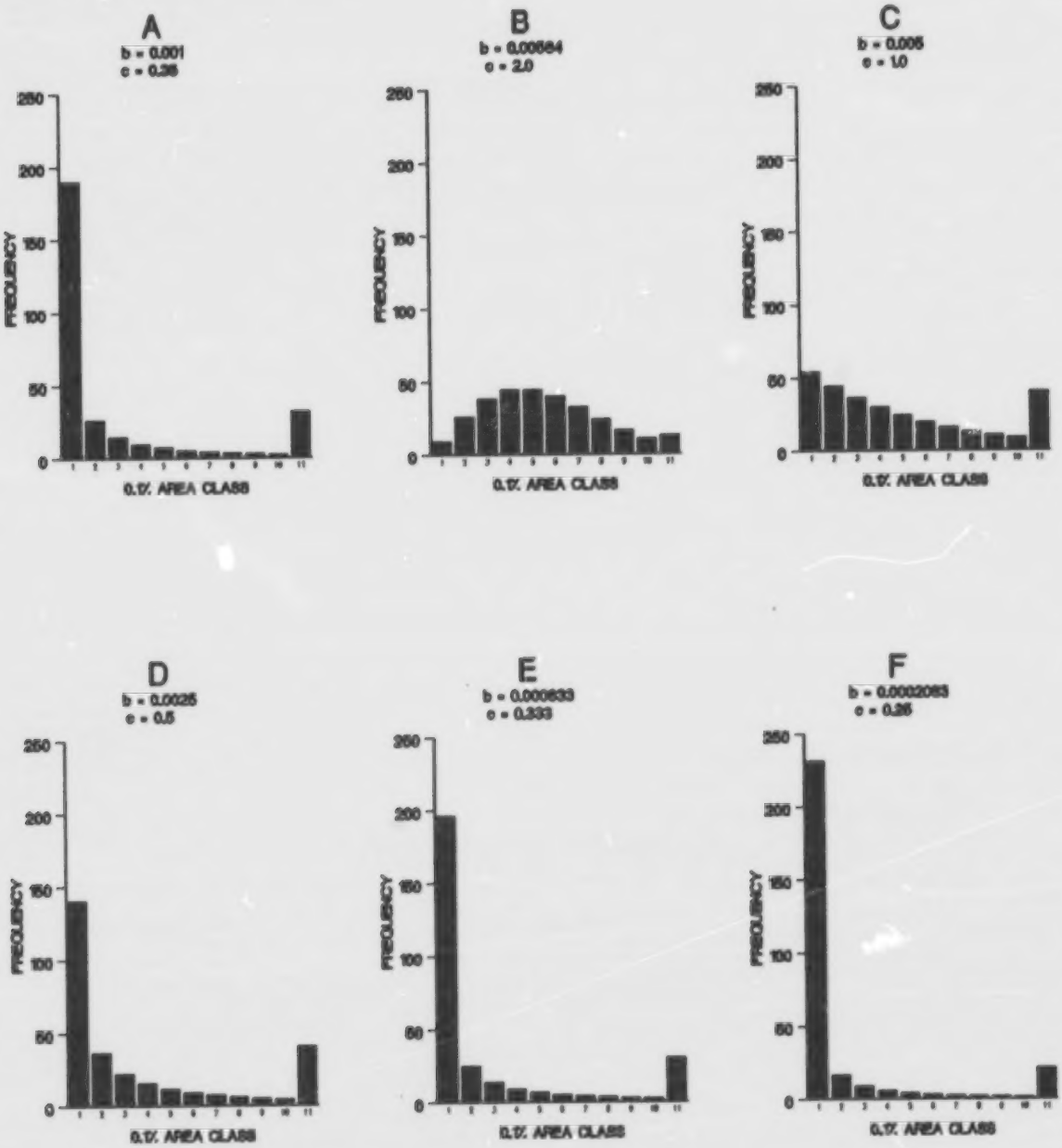

Figure 2. Theoretical Weibull distributions for a mean annual burnt area of 0.5 per cent by 0.1 per cent area classes (class 11 is the frequency for areas >1%). Distribution A is that used in Tests 1 - 10.

i.e. either there was no fire or the whole forest was burnt). The values of b and c should be chosen with care to take into account the size of the forest and also the fire history in the region.

Once the area that is burnt in any year has been determined, FIRFOR allocates this area to the age classes in each site class using the formula:

$$P = 0.00284+0.5047\times10^{-11}A^5-0.9224\times10^{-9}A^2+0.0007492\ell nA - 0.3353\times10^{-8}A^4+ 0.003540A+0.4139\times10^{-8}A^3S+0.8554\times10^{-8}A^3 +0.7035\times10^{-9}AS$$

where P is the relative proportion of the one-year age class that is burnt. This complex hypothetical function (illustrated in Figure 3) has been designed to reflect the fact that forest stands are more susceptible to fire at certain stages of their development (e.g. at the onset of crown closure and at stand break-up).

The user of FIRFOR has the option of choosing a fixed proportion of the area to be burnt each year, and of distributing that area equally among the age classes.

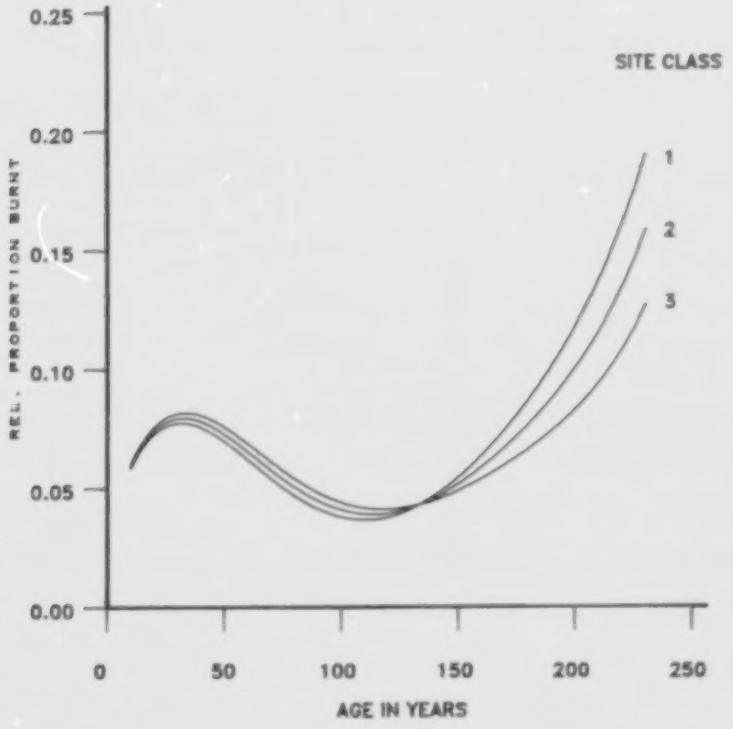

Figure 3. Relative proportion of the area in each one-year age class that is burnt each year.

METHOD

The FIRFOR model has been programmed in FORTRAN-77 for a Digital Equipment Corporation VAX/785 Computer. A listing of the program, a listing and description of the input and output files, and a summary flow-chart are given in Appendix I. It is an "interactive" program: the user sits at a terminal and responds to the input requests posed by the program. This process will be illustrated here using, as an example, Test 1. In each case the information entered by the user is underlined.

Do you want the results of this test plotted using SAS/GRAPH (Y/N)? Y

At the Institute, there are two methods of plotting the results of a FIRFOR test. The first method, that can produce graphs on the screen of a graphics terminal or on a plotter, uses SAS/GRAPH* procedures.

By responding positively to this question, a file (SGRAPH.DAT) is opened. The output that is stored on this file can be readily converted to SAS data files for plotting volume and area harvested, growth and net change, and residual forest volume on time for the period of the test. The second method uses programs developed by Institute staff to plot the results on a Nicolet ZETA8 plotter.

ENTER random number seed (<2147483647): 886332245

The number entered here is used as a "seed" to the computer's random number generator. Random numbers may be required for two purposes: first, to generate a random distribution of areas by one-year age classes at the start of a test (if that option is chosen) and, secondly, to generate the areas that are burnt each year if the Weibull distribution option is selected. If the same value is used in each test, the random number sequence will be identical and, for example, the patterns of areas burnt each year will be the same. The final value of the random number is printed at the end of each test so that, if it is desired to extend the period of the test further, it can be entered at the start of the continuation test.

GENERATE INITIAL FOREST

Do you want:

1. a UNIFORM DISTRIBUTION OF area by one-year age classes
2. a RANDOM DISTRIBUTION of area by one-year age classes
3. a previously generated forest?

ENTER 1, 2 or 3: 3

INPUT file name on which initial forest data are stored:

FOREST.DAT;1

---

*SAS Institute Inc. 1985.

The present version of FIRFOR assumes a very simple form of forest that may consist of only one species with up to three site classes. The user does have the option of having a uniform or random distribution of areas in the initial forest, or the forest that has been saved at the end of a previous test may be used. For this, and most subsequent tests, the initial forest data were derived from the basic forest (with its uniform distribution of age classes) that was described earlier. This forest was "managed" for a period of 300 years and its final state stored on file FOREST.DAT;1. As for the basic forest, there will be 25 000 ha each of site classes 1 and 3, and 50 000 ha of site class 2.

For later versions of FIRFOR, it is intended that the input for the initial forest will be generated from a GIS database for the forest that is being studied. This would include several species, or stand types, each requiring its own growth function.

Choose the yield function to be used in this test from:

1. Plonski's yield tables for black spruce
(merchantable volume in m^3/ha)
2. Plonski's yield tables for red pine
(merchantable volume in m^3/ha)
3. Reserved for future use

ENTER your choice (1, 2 or 3): 1

At present the user has the choice of only two growth functions although a third could be readily added if required. The function for black spruce has been given in equation [1] and a similar function has been derived for red pine, a more productive species.

Do you want a data file established to plot yield curves (Y/N)? N

This option allows the user to plot the yield curves (similar to those given in Figure 1) if desired. Plotting at the Institute is done on a Nicolet Zeta 8 plotter using special routines developed by Institute staff. Plotting may also be done with SAS/GRAPH procedures.

The relative proportion of the area in an age class that is burnt in any year may be:

1. Constant
2. Dependent on age and site class

ENTER your choice (1 or 2): 2

Do you want a data file established to plot fire/stand age probability curves (Y/N)? N

The proportion of the total area that is burnt in any year may be:

1. Constant
2. Variable with a Weibull distribution

ENTER your choice (1 or 2): 2

ENTER "B" and "C" parameters of the Weibull function:

CDF = 1-exp[-(X/B)**C]

where X = the proportion of the area that is burnt

e.g. ENTER 0.001,0.4: .001,.35

This section permits the user to choose how the annual fire loss will be predicted and distributed among the age and site classes in the forest. In this example, fire will be allocated proportionally using the function illustrated in Figure 3, and the annual area burnt will be selected at random from the Weibull distribution shown in Figure 2.

FOREST MANAGEMENT OPTIONS:

1. No management.
2. Harvest the "overmature" stands in each site class as they reach a specified age.
3. Harvest the "overmature" stands plus other stands as they become mature (at a rotation age specified for each site class).
4. Harvest a specified annual area or volume. Salvageable wood is harvested first followed by stands in order of declining volume/ha with optional constraints on minimum volume/ha or minimum age.
5. As for 4 except that stands are selected in order of increasing annual growth.

With any of the options there is the option of salvaging a specified percentage of the annual volume loss due to fire within a specified period (< 5 years) if the area burnt exceeds a specified percentage of the total area.

ENTER your management option (1 - 5): 5

ANNUAL HARVEST:

For management options 4 and 5, the annual harvest may be regulated by:

1. AREA, with constraints on the volume that should be harvested each year (IAV = 1), or
2. VOLUME, with constraints on the area that should be harvested each year (IAV = 2).

The user must enter the prescribed area or volume to be cut each year and the range within which each of these will be allowed to vary. If the harvest is controlled by area, the prescribed area will be cut each year, except when the associated volume cut falls outside the prescribed volume range. When this happens, the area that is cut will be adjusted (within its range) until either the volume cut comes within the prescribed range or an area limit is reached. A similar procedure is used when the harvest is controlled by volume.

ENTER the appropriate value for IAV (1 or 2): 2

ENTER volume (m^3) to be harvested each year and lower and upper limits (e.g. 120000,100000,125000):
125000,120000,130000

ENTER lower and upper limits on area (ha) to be harvested each year (e.g. 800,2000):
600,1000

Do you want the salvaging option (Y/N)? Y

FIRFOR offers the user five elementary management options related to the method of selecting stands for harvesting. The simplest of these is "no management" (Option 1) where the forest would follow its natural cycle. Each stand would "die" when it reached zero volume (see Figure 1), or when it was destroyed by fire, and would then be immediately replaced by a stand of the same species that followed the same growth pattern. Unless the salvaging option was selected, there would be no yield from the forest.

In Option 2, the age at which the stands in each site class must be harvested is specified. All stands greater than the specified age for the site class would be harvested during the first year. This could, if the harvest age was much less than the age of the oldest stands, result in an excessively large cut for that year. After the first year, the stands are harvested as they reach the specified age and this would result in a more uniform annual yield (until the stands cut in the first year were ready for cutting again).

In Option 3, a modification of Option 2, two harvesting ages are specified for each site class. One is the age at which "overmature" stands will be harvested and the second is the rotation age (usually the age at which mean annual increment is maximum). For example, the first age may be set at 145 years and the rotation age at 110 years. All stands greater or equal to 145 years plus those stands that are 110 years old would be harvested in the first year. From year 2 to year 35, stands would be cut when they reached either 110 years or 145 years of age. After year 35 there would be no stands greater than 110 years. In this way the harvesting of the "overmature" stands is spread over a number of years instead of being concentrated in the first year.

The first three options will give an idea of the long term sustainable yield of the forest according to a set of simple rules for scheduling the harvest. No attempt is made to regulate the annual cut. This regulation may be achieved by Options 4 and 5, either by area control (with volume check) or by volume control (with area check). The method of doing this is described in the above explanation that appears on the terminal screen each time FIRFOR is run. For options 4 and 5, stands are selected for harvesting according to priorities set by specified rules. In Option 4, stands are selected in order of decreasing volume per ha until the annual cut is reached. In Option 5, selection is made in order of increasing annual growth (keeping in mind that growth may be negative, for example, after age 150 in Figure 1). Thus the first stand to be selected would be the stand that showed the greatest decline in volume per ha over the next year. The second would be the stand showing

the next greatest decline and so on until, if necessary, all the stands with negative growth were scheduled. The next stand to be chosen would be the stand with the smallest positive growth. This process would continue until the prescribed area to be harvested or AAC had been reached and, if possible, the area and volume cut fell within the prescribed limits. It should be noted that the annual harvest may sometimes not fall within the prescribed limits because of other constraints that are placed on harvesting. These are described below.

Acceptance of the salvaging option permits the harvesting of a portion of the wood that is burnt in any year. Where an annual harvest has been specified, the salvaged volume is applied first to this cut before any stands are scheduled for harvesting.

COMPLIANCE FACTOR:

It is usually not possible in practice to achieve 100% compliance with the rules laid down in management options 2-5. Some stands that are scheduled for harvesting may not be economically accessible at present. In any one year, the manager may prefer to consolidate harvesting in specified areas by exchanging "scheduled" stands for "non-scheduled" stands (that are near to harvesting) in the harvesting areas. Such non-compliance with the prescribed harvesting rules is simulated by applying a "compliance factor". A compliance factor of 50% would mean that only 50% of the stands scheduled for harvesting would be actually harvested, the balance being achieved by harvesting 50% of the next stands in order of priority. NOTE: a scheduled area of 1 ha or less will be harvested in its entirety, regardless of the value of the compliance factor.

ENTER the compliance factor (%) (e.g. 50 for good, 25 for average, 10 for poor): 100

The above explanation of the Compliance Factor appears on the terminal screen each time the model is used. The suggested percentage values for "good", "average", and "poor" would at first glance appear to be unreasonably low. However, it should be realized that if only 50 per cent of the scheduled stands are actually harvested in the current year the remaining 50 per cent will probably again be scheduled in the next year of which half will be actually cut. After five years, approximately 97 per cent of the stands originally scheduled for harvesting in the first year would have been actually cut. The corresponding value for the "poor" compliance (10%) is 41 per cent.

ENTER minimum volume for harvesting (m^3/ha): 90

ENTER minimum age for harvesting: 75

ENTER percentage of fire-destroyed wood that can be salvaged: 25

ENTER salvage period (< 5 years): 3

(half salvaged in year 1, one-third in year 2, one-sixth in year 3)

ENTER percentage of the area burnt in any year, above which salvaging operations will take place: 1

For options 4 and 5, the user may wish to impose a number of constraints on the stands that can be harvested. Harvesting may be restricted to stands greater than a certain minimum age. Imposition of this constraint may be necessary if option 5 is chosen to prevent the harvesting of slow-growing young stands (with Plonski's yield tables for black spruce, growth in merchantable volume is greatest at the age where the stands begin to have merchantable wood and declines thereafter so that this problem will not occur). Harvesting of stands containing less than a specified volume of merchantable wood may not be economical and the stands may be left to die and regenerate naturally.

If the salvaging option is chosen, the percentage of the fire-damaged wood that can be salvaged must be specified. This will usually be less than 100 per cent as some of the wood may be damaged to the point where it has no commercial value, or the stands may be in remote areas and thus uneconomical to harvest. Damaged wood must be harvested within a few years or it will deteriorate further and the user can specify a salvage period of from one to four years. The model is programmed to harvest most of the wood in the first year of the period with declining volumes in succeeding years, as indicated in this example for a three-year salvage period. If the area lost to fire in any year is small, the manager may not wish to salvage any wood. In this example, salvaging only takes place if more than one per cent of the area is burnt.

ENTER Test No. (Max. of 8 characters): 1-5V

ENTER date in metric format, e.g. 85.1122 for 22 NOV: 1985: 86.1202

ENTER Title (Max. of 45 characters): TEST 1: OPTION 5V - AAC = 125000 m^3/YR

Do you want a tabular summary of the initial forest (Y/N)? Y

Area and volume are printed for each age class.
ENTER number of years in each age class: 25

At what intervals during the run do you want age-class distribution tables printed?
ENTER the number of years: 25

Do you want the initial and periodic age-class distributions plotted (Y/N)? Y

ENTER number of years in each age class: 10

At what intervals during the run do you want the age-class distributions plotted?
ENTER number of years: 50

At what interval do you want summary results printed during the simulation run?
ENTER the number of years: 5

Do you want the results (residual volume, harvest, growth, etc.) plotted over time (Y/N): Y

Do you want to save the final state of the forest (Y/N)? N

This set of questions allows the user to plan the type of output that he requires. The test number and date are printed at the top of each page of the output files. The title is printed on the first page and on each graph. Plotting of the graphic output is not done "online" but requires the running of additional programs to prepare the data for the Zeta 8 plotter. Alternatively, the graphs may be prepared using SAS/GRAPH.

ENTER number of years for this simulation run: 300

Finally, the number of years for the simulation run must be specified.

The file names on which the different types of output are stored are given in Appendix I. These files may be listed on the terminal screen or on the system's printer. Examples of the output are given also in Appendix I.

RESULTS

The results of Test 1 are described here in some detail. A number of additional simulation tests were done in each of which only one or two of the options, or the values of one or two of the input variables, were changed. The results of these tests are compared so that the user may obtain some idea of the effects of the different variables and options on residual volume, annual harvest, fire losses and growth. The tests were not replicated. In all the tests, the same initial forest (consisting of 100 000 ha of black spruce) and the same random number seed were generally used.

Test 1. Option 5 (Annual harvest = 125 000 m^3/yr)

The values of the input variables for this test have been given in the Method section. The area burnt each year was drawn at random from the Weibull distribution illustrated in Figure 2 and allocated among the age classes in the proportions shown in Figure 3. The annual harvest was prescribed at 125 000 m^3 but, if necessary, could range between 120 000 and 130 000 m^3. The area harvested each year (and therefore requiring regeneration) should be preferably within the range 600 - 1000 ha/year. Stands were selected for harvesting on the basis of projected growth: stands with the greatest negative growth were cut first followed by stands with the smallest positive growth until the annual cut was achieved. Stands with less than 90 m^3/ha or that were younger than 75 years were excluded from harvesting. If more than one per cent of the area was burnt in any one year, 25 per cent of the merchantable timber on that area was salvaged over the succeeding three years. The test was run for 300 years. Tabular output is given in Appendix I.

Fire Losses. Figure 4 shows the areas burnt and harvested each year. Except for burnt areas that will be salvaged in the three succeeding years, these

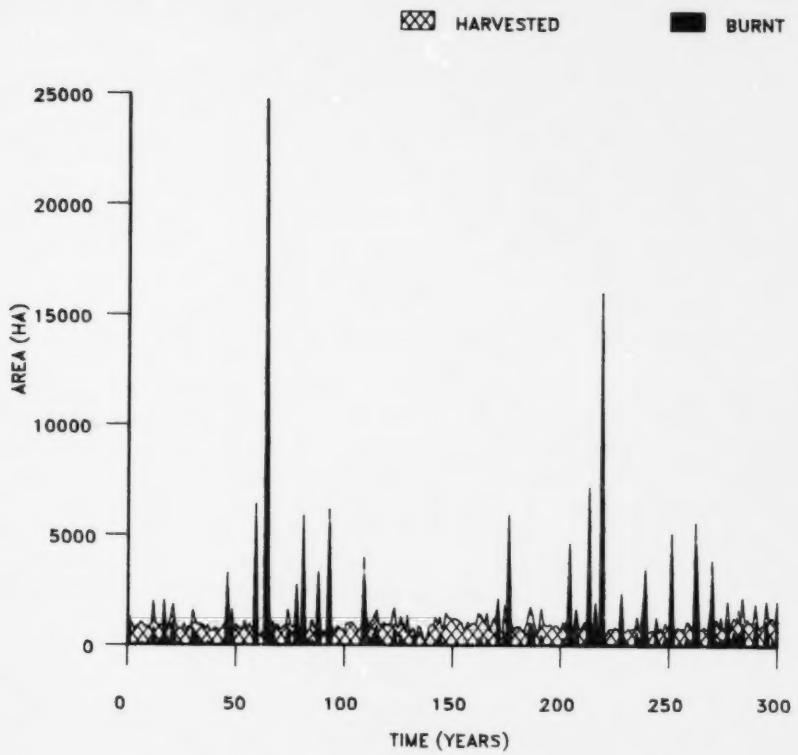

Figure 4. Test 1: annual areas burnt and harvested.

areas (together with any areas that are salvaged as a result of fire in previous years) would be regenerated immediately. Year 64, when nearly 25 per cent of the forest was destroyed, was the worst fire year followed by year 219 with 15 per cent. By way of contrast, in 270 of the 300 years less than one per cent of the area was burnt while the average area was 477 ha.

Annual Harvest. The prescribed AAC of 125 000 m^3 was achieved in about two-thirds of the years and was exceeded in only six years (Figure 5). The reason for this becomes clear when Figure 5 is compared with Figure 6: in each of the six years, the additional volume was harvested to bring the cut area up to the minimum level of 600 ha. The minimum harvest of 120 000 m^3 was obtained more often and was an attempt, usually unsuccessful, to restrict the area cut to 1000 ha or less. Following the disastrous fire years, 64 and 219, a large proportion of the annual harvest consisted of salvaged wood. Burnt wood was salvaged in 27 per cent of the years. Perhaps the most interesting feature illustrated in Figure 5 is the shortfall in annual harvest for eight years during years 127 - 139. This is because of the bad fire year some 70 years previously that resulted in a shortage of stands of merchantable wood (90 m^3/ha). A similar, but less serious, shortfall would probably have occurred at about year 310 if the simulation had been continued. The average annual harvest was 121 860 m^3 and the average area cut was 901 ha.

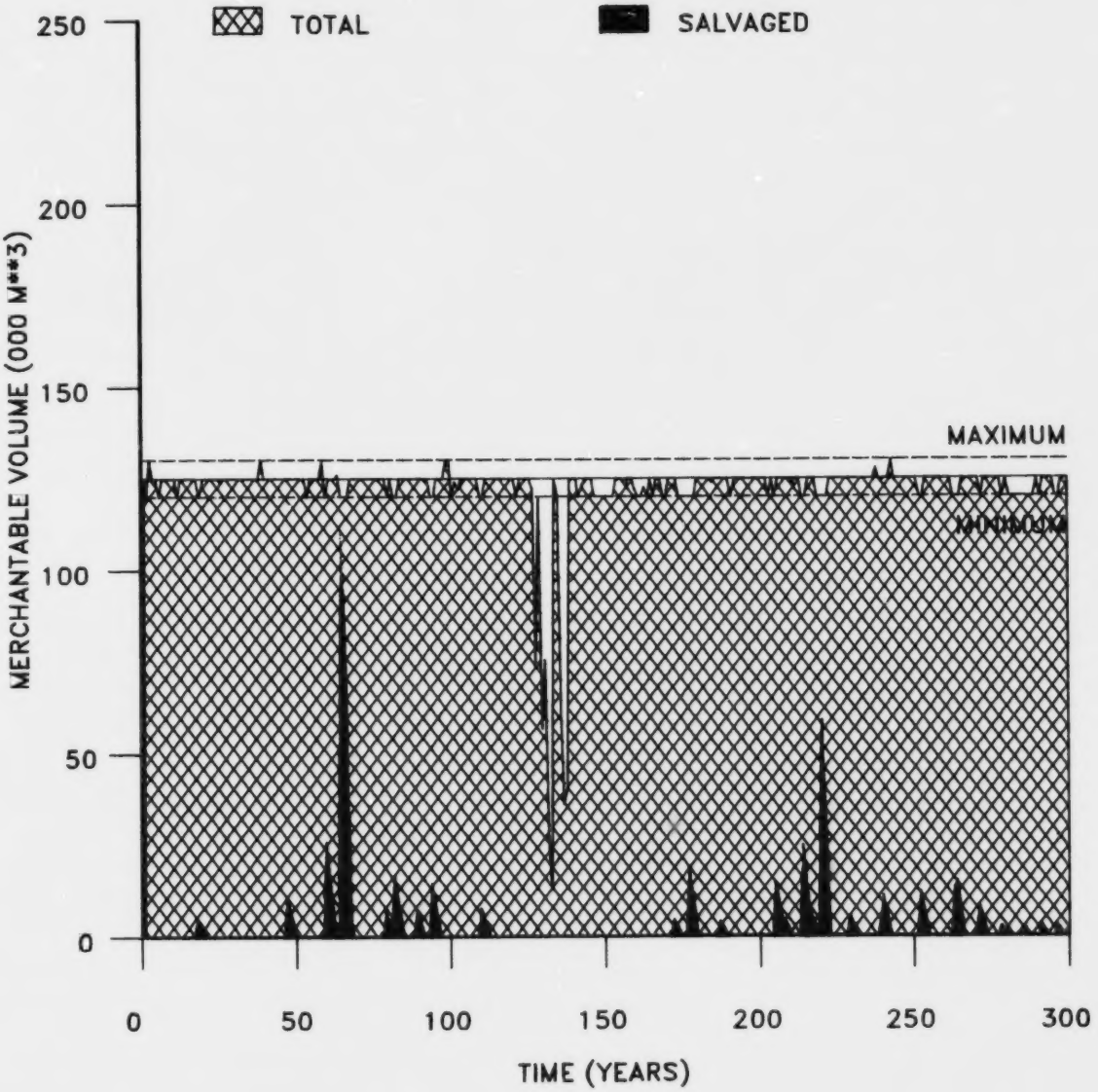

Figure 5. Test 1: annual cut.

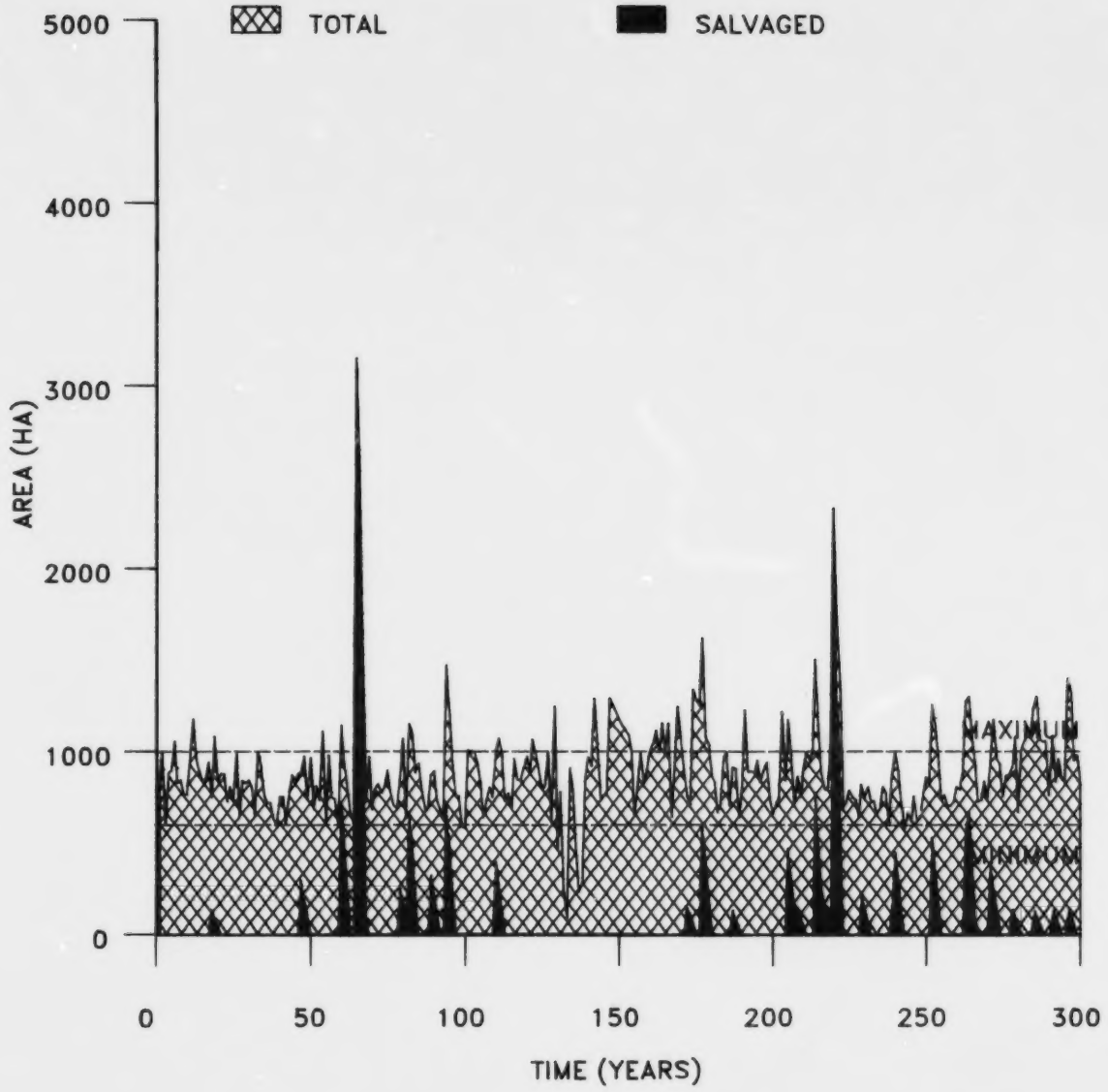

Figure 6. Test 1: annual cut area.

Annual Growth and Net Change in Volume. In Figure 7, the upper boundary of the cross-hatched area shows the annual growth in merchantable wood. This varies between 93 and 160 thousand m^3/year. From this upper level the volume harvested and the net volume lost to fire (the total volume on the burnt areas minus the volume that can be salvaged) is subtracted to give the net change in volume each year (the lower boundary of the solidly shaded area). Because of the pattern of fire losses, the net change fluctuates quite wildly between a net loss of 677 thousand m^3/year and a net gain of 118 thousand m^3/year. Over the 300 years, the average growth was 130 thousand m^3/year and the average net change was -560 m^3/year.

Forest Inventory. The inventory of merchantable wood in the forest for the 300-year period is illustrated in Figure 8. There is a steady increase in merchantable volume until year 64, when nearly 900 000 m^3 were destroyed. As a result of this bad fire year, the inventory continued to decline for the next sixty years, reaching a low of 2.25 million m^3 in year 126, as younger and lower-volume stands were sacrificed to meet the annual harvest requirements. As noted previously, the number of available merchantable stands declined to the point that the annual requirements could not be met for several years. This was followed by a period of steadily increasing inventory as the stands that were regenerated in year 64 reached merchantable age. The pattern appears to be repeating after the second bad fire year 219. It thus appears that, under the present patterns of annual fire loss, the forest will never reach a steady state.

Age-Class Distribution. The distribution of area by 10-year age classes (1-10, 11-20, etc.) is shown at 50-year intervals in Figure 9. There is remarkably little evidence of the reverse J-shaped distribution normally associated with forests where fire plays an important role in their development (Van Wagner 1978). The distributions are fairly uniform, at least for the selected years, with the exception of "peaks" for age classes whose stands originated during one of the bad fire years (64 or 219), e.g. the 30-year age class in year 100. This particular peak is still noticeable in the second rotation (see the 20-year age class in year 200). Generally, the oldest age classes contain a higher than average proportion of the poorer site classes.

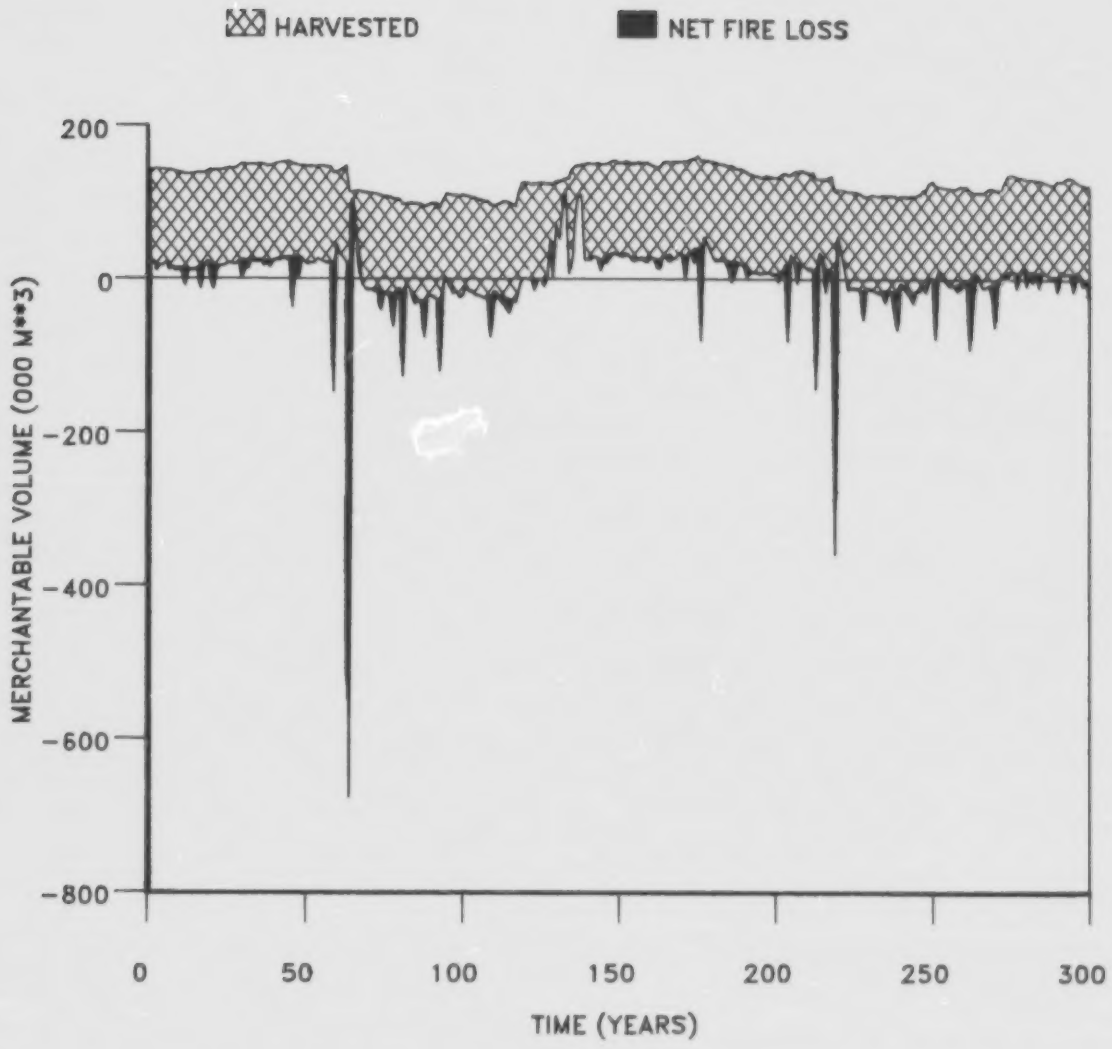

Figure 7. Test 1: gross annual growth and net change in volume.

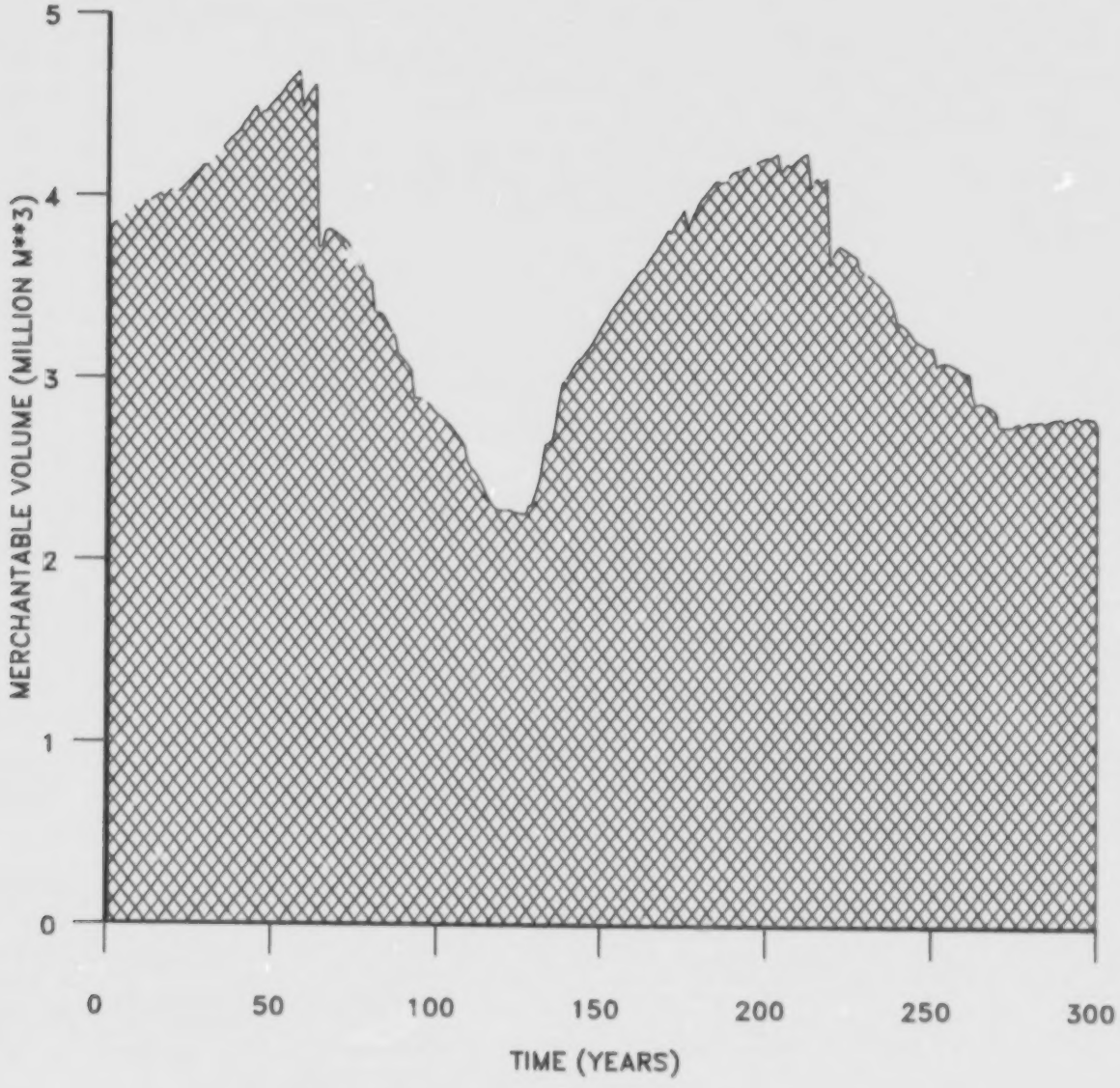

Figure 8. Test 1: residual forest inventory.

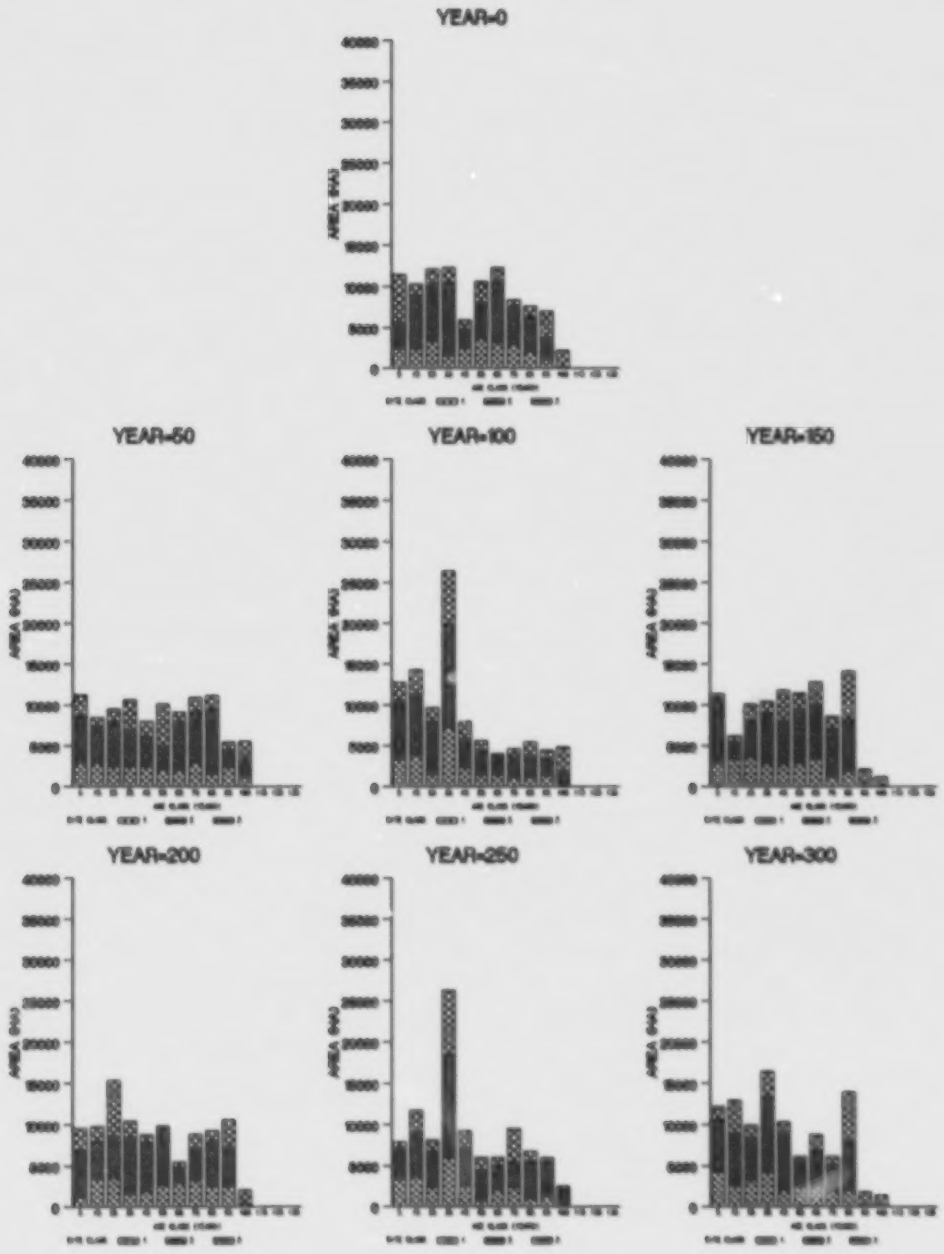

Figure 9. Test 1: age-class distribution histograms.

Test 2. Option 5 (Annual harvest = 900 ha/year)

Test 2 was identical to Test 1 except that the annual cut was controlled by area with a volume check. The area that should be cut year year was set at 900 ha (approximately the average area that was cut each year in Test 1). The area range was again 600-1000 ha and the volume range was again 120-130 thousand m^3. The actual area cut each year is shown in Figure 10. Apart from the two bad fire years, the upper limit was never crossed and the annual cut only fell below the lower limit on two occasions. However, within the allowable range there was considerable fluctuation. This variation was also apparent in the volume of wood that was cut each year (Figure 11). The lower limit of 120 thousand m^3 was not reached on 73 occasions (in contrast to only eight under volume control). These deficits were spread throughout the 300-year period of the simulation but were more frequent in the period between years 125 and 175. The upper volume limit was surpassed on several occasions, particularly around year 250. The average area cut (853 ha) was five per cent less than in Test 1 while volume (117 722 m^3) was 11 per cent less.

The patterns in gross annual growth and net change, residual forest inventory, annual area losses, and age-class distribution were similar to those obtained for Test 1, differing only slightly in magnitude.

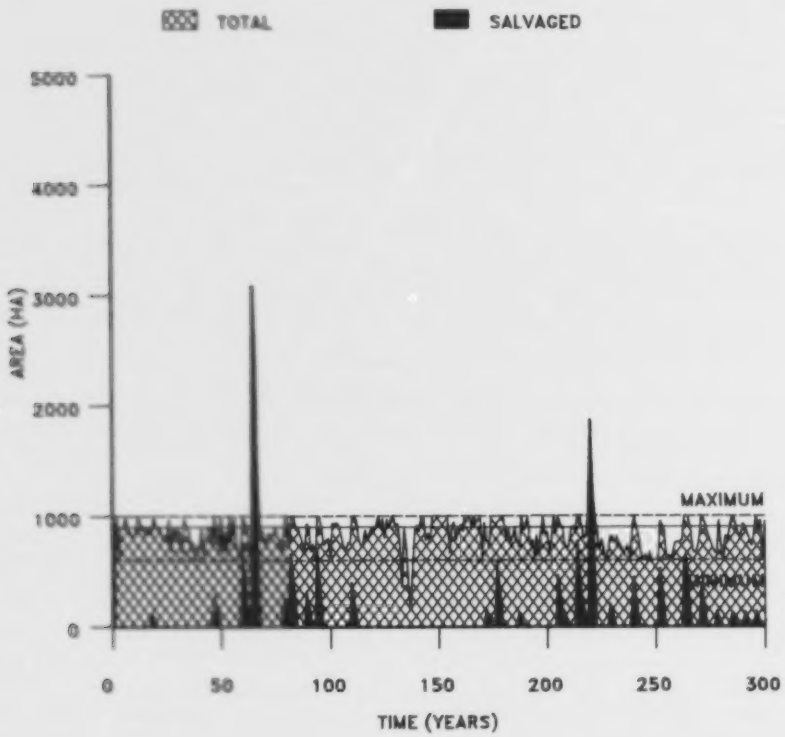

Figure 10. Test 2: annual area cut.

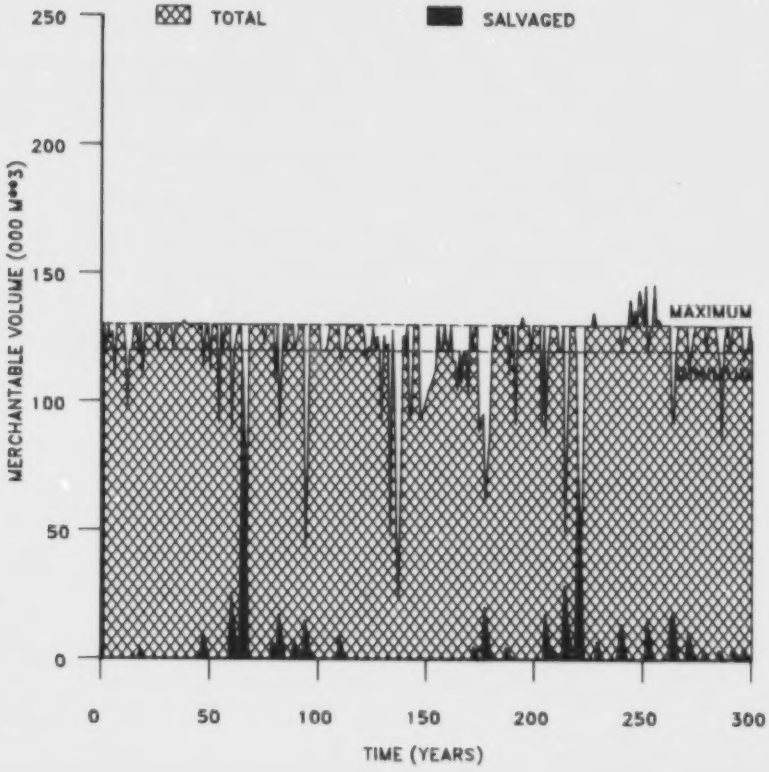

Figure 11. Test 2: annual cut.

Test 3. Option 5 (Annual harvest = 125 000 m^3; constant fire loss)

The basic difference between Test 3 and Test 1 was that a constant annual fire loss was assumed instead of a random loss. This annual loss was set at 0.477 per cent of the total area, the same as the average annual loss in Tests 1 and 2. Because this area is always less than the minimum area for salvaging (one per cent in Tests 1 and 2), the amount of wood that could be salvaged was changed from 25 to 20.6 per cent, the latter value being the average amount salvaged in Test 1, and the minimum burnt area for salvaging was reduced to zero so that 20.6 per cent of the burnt wood was salvaged each year. Apart from these changes, Tests 1 and 3 are identical.

Because of the elimination of the wide variation in annual fire losses the patterns of harvesting and growth are more uniform, as would be expected. The annual harvest (Figure 12) never exceeds the specified AAC (125 000 m^3) and, for the first 200 years, fluctuates between the minimum and the specified AAC. For the next 60 years, the harvest seldom exceeds the minimum requirement of 120 000 m^3 and, after year 265, that requirement is

only met on six occasions. This probably indicates that, under the present conditions, the forest is incapable of maintaining in the long term an AAC of 125 000 m^3. This is also reflected in the steady decline of the forest inventory (Figure 13), although there is some indication of a levelling off in the last 40 years. The average annual harvest (120 756 m^3) was slightly less than in the two previous tests.

The most striking differences are in the pattern of the age-class distributions (Figure 14). The variations in the initial distribution (year 0) have been largely smoothed out by year 50 and a fairly consistent pattern occurs after year 200. The steady state forest shows the area in each age class declining with increase in age to age 75 years. Those stands in age classes greater than 75 are confined to site classes 2 and 3 and, for the most part, contain volumes of less than 90 m^3/ha (Figure 1). This pattern, lying between the rectangular distribution of the managed forest in which fire is excluded, and the reverse J-shaped distribution of the unmanaged forest that is regulated by fire alone, confirms the findings of Van Wagner (1983).

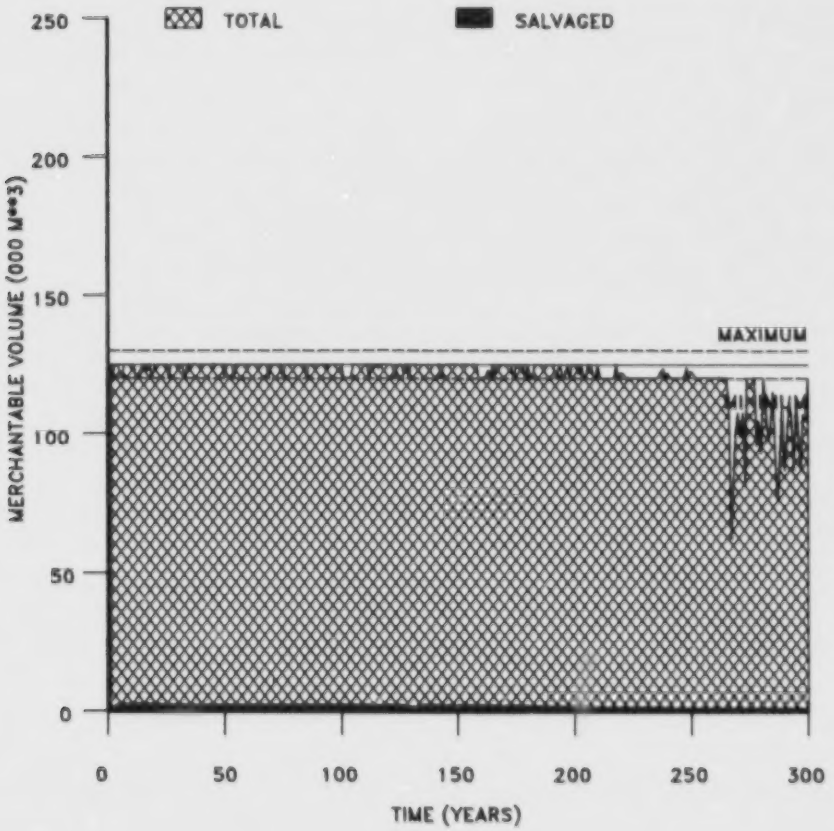

Figure 12. Test 3: annual cut.

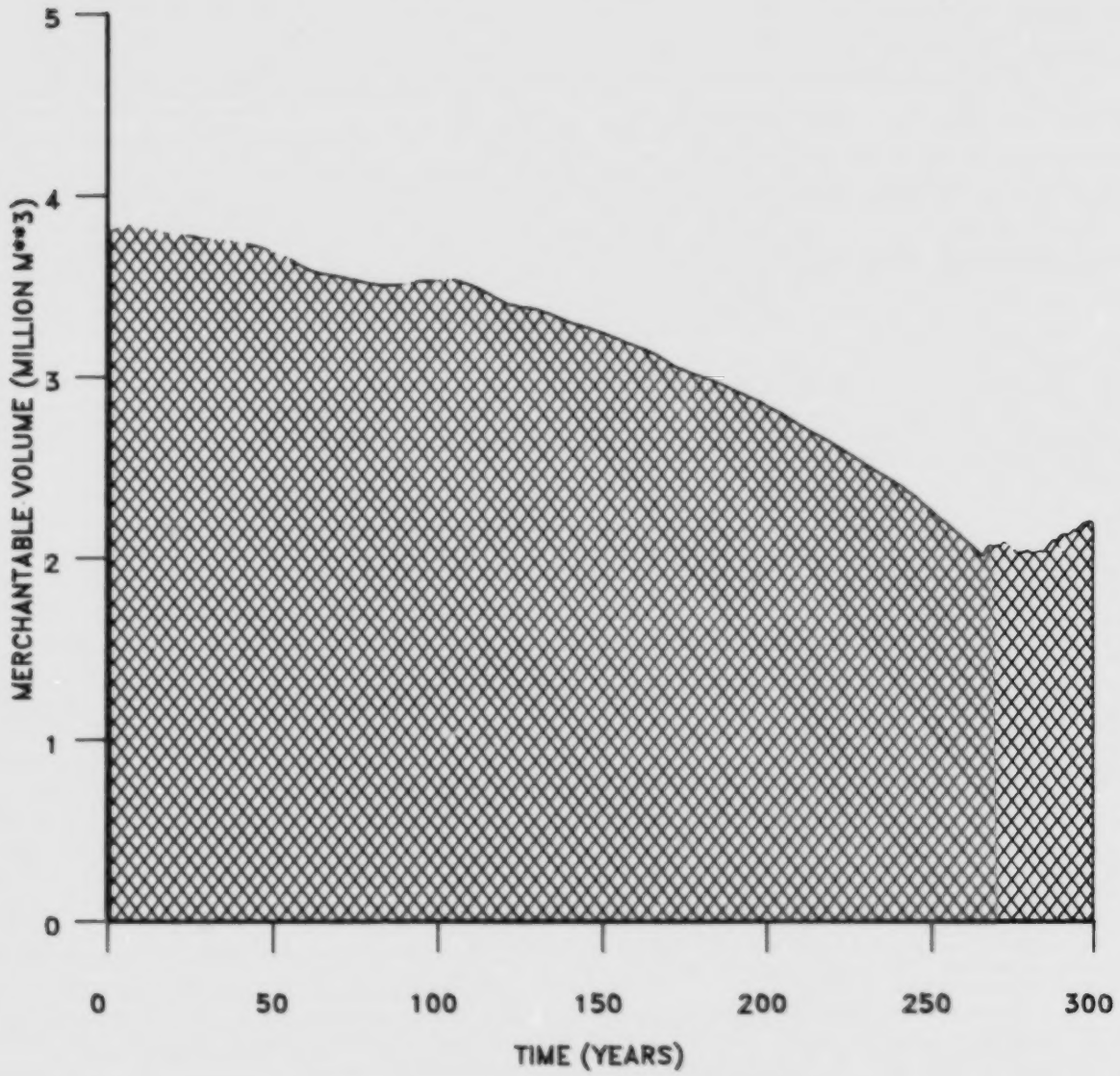

Figure 13. Test 3: residual forest inventory.

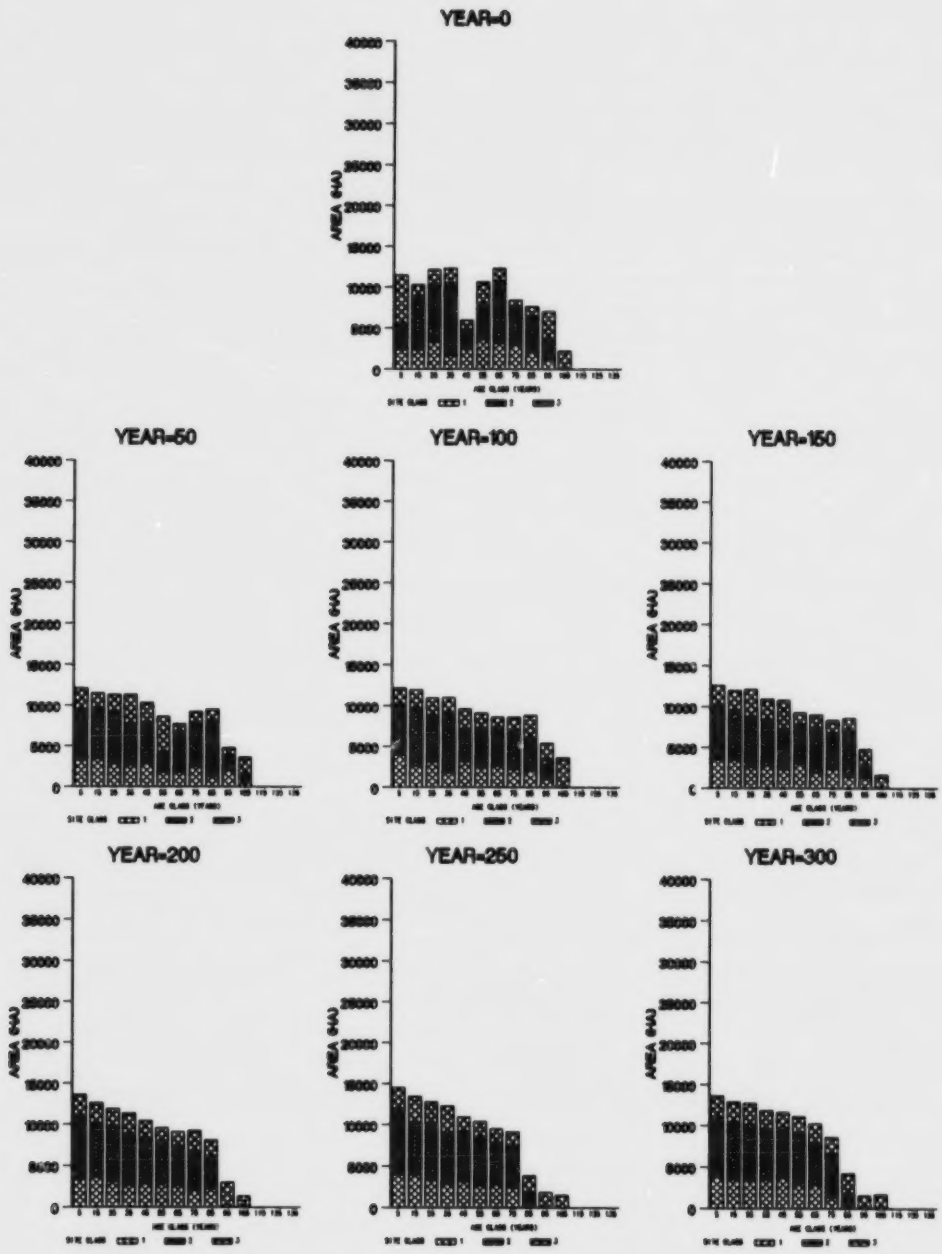

Figure 14. Test 3: age-class distribution histograms.

Test 4. Option 5 (Annual harvest = 125 000 m^3; no maximum restriction on age or volume/ha for harvesting).

Test 4 demonstrates quite dramatically what happens if no restrictions are placed on the minimum volume per ha and the minimum age of stands that can be harvested. The effect of this is to concentrate harvesting among the slower growing site class 3 stands and, only when merchantable stands in this class have been eliminated, to fell stands of higher site quality (see Figure 1). During the first 100 years, the specified AAC is seldom exceeded (Figure 15) while, because the cut is obtained from stands of low volume, the upper area limit is often exceeded (Figure 16). Because of the changes in age-class distribution, the effects on the annual harvest of the disastrous fires in year 64 are felt earlier than in Test 1. The lack of constraints on harvesting permits all stands containing merchantable wood to be harvested in year 118 in an attempt to meet the specified annual cut and this is continued for the remainder of the 300-year period so that the forest never recovers. The age-class distribution in year 150 (Figure 17) shows that none of the stands contains merchantable wood.

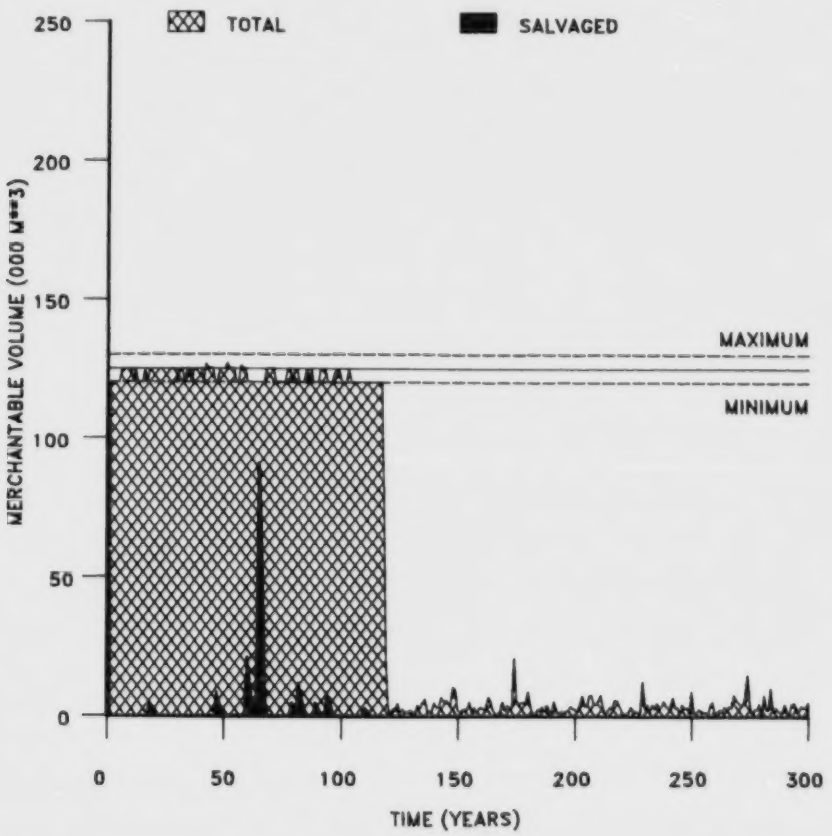

Figure 15. Test 4: annual cut.

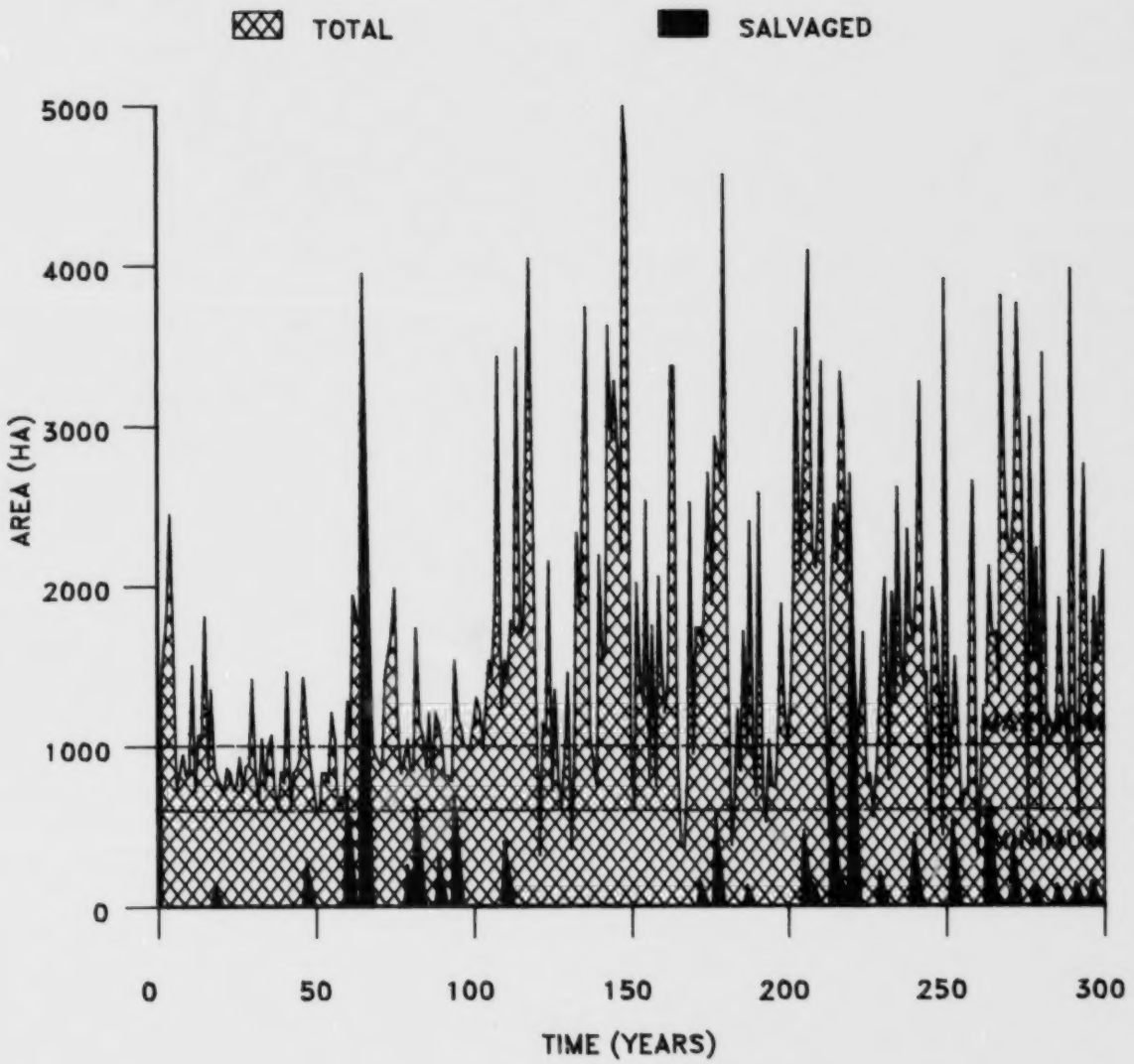

Figure 16. Test 4: annual area cut.

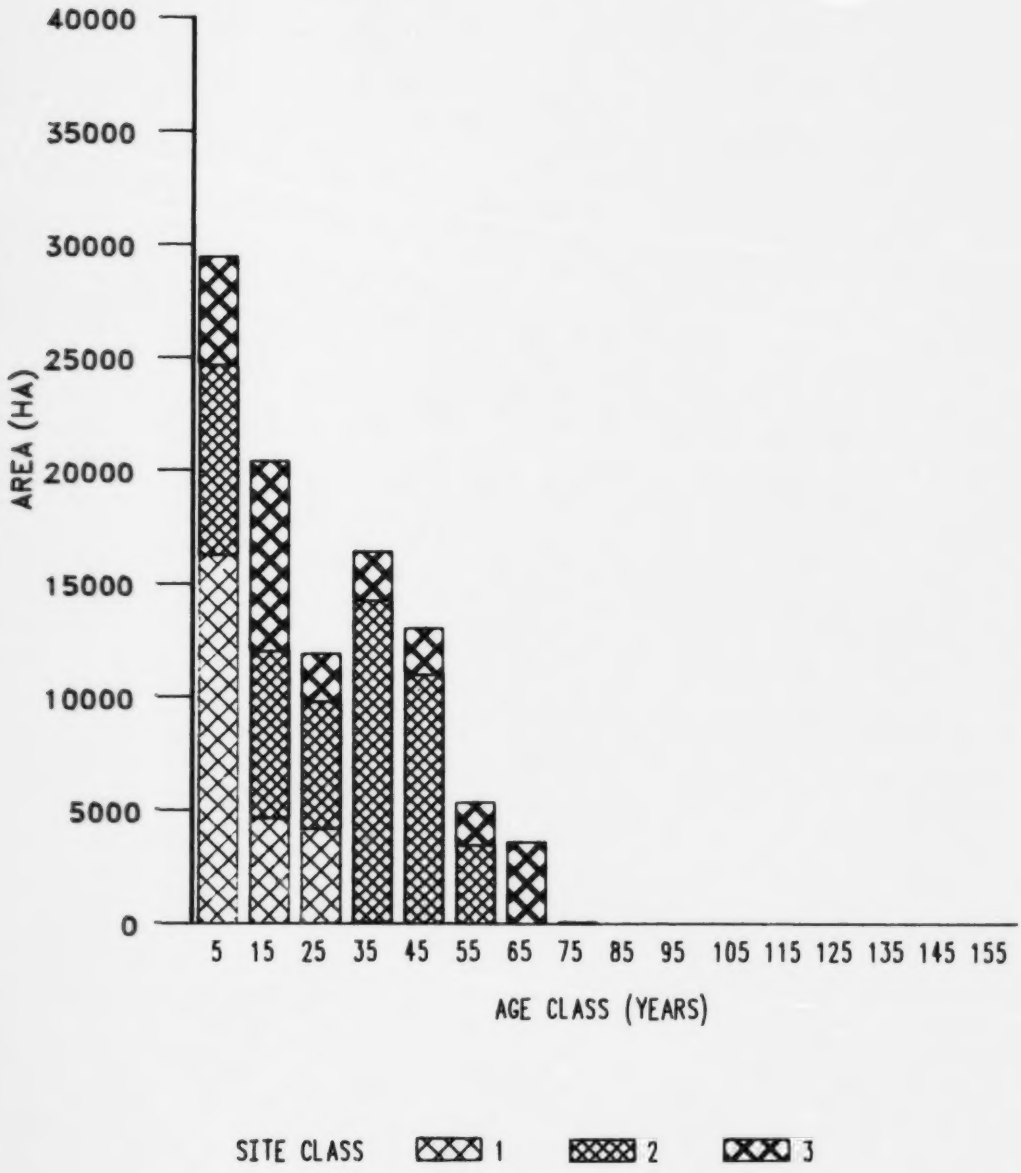

Figure 17. Test 4: age-class distribution at the end of year 150.

Test 5. Option 5 (Annual harvest = 125 000 m^3; compliance factor = 10%).

In the first four tests, it was assumed that there was absolute compliance, wherever possible, with the rules for selecting stands for harvesting. In practice, absolute compliance with such rigid rules is seldom possible because of operational constraints that are not considered in this model. This non-compliance may affect the harvesting pattern and is simulated in the model by assuming that, in any year, only a percentage (the Compliance Factor specified by the user) of the stands that would normally be scheduled for harvesting would actually be cut. The balance of the annual harvest would come from the next stands in the "queue" for harvesting. In Test 5, a low compliance (10 per cent) has been assumed. When compared with full compliance (Test 1 - Figure 5), the effects appear to be twofold. First, the bad fire year 64 has a more serious effect: the shortfall in the annual harvest that occurs some 50 years later lasts longer (years 106-138), although at least 50 per cent of the prescribed cut is obtained each year (Figure 18). Secondly, apart from the 20-year shortfall period, the flow of harvested wood appears to be more uniform than when there was full compliance with the rules. The prescribed annual cut was achieved nearly 90 per cent of the time and was exceeded on only three occasions (years 249-251). This more uniform harvesting pattern is also reflected in a more even distribution of the area harvested each year (Figure 19). Apart from the two bad fire years (64 and 219) and the shortfall period, the area cut each year generally fell within the prescribed range (600-1000 ha).

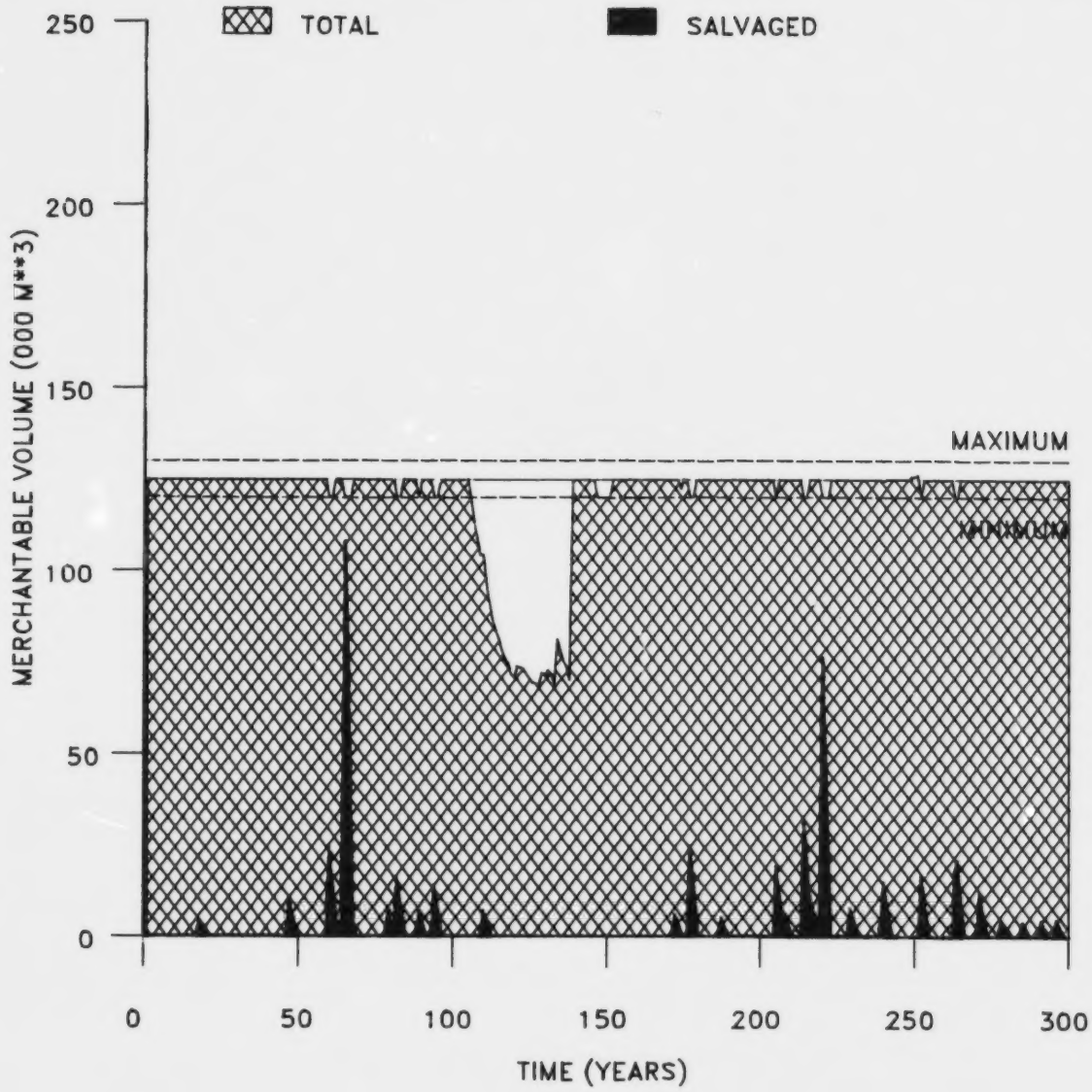

Figure 18. Test 5: annual cut.

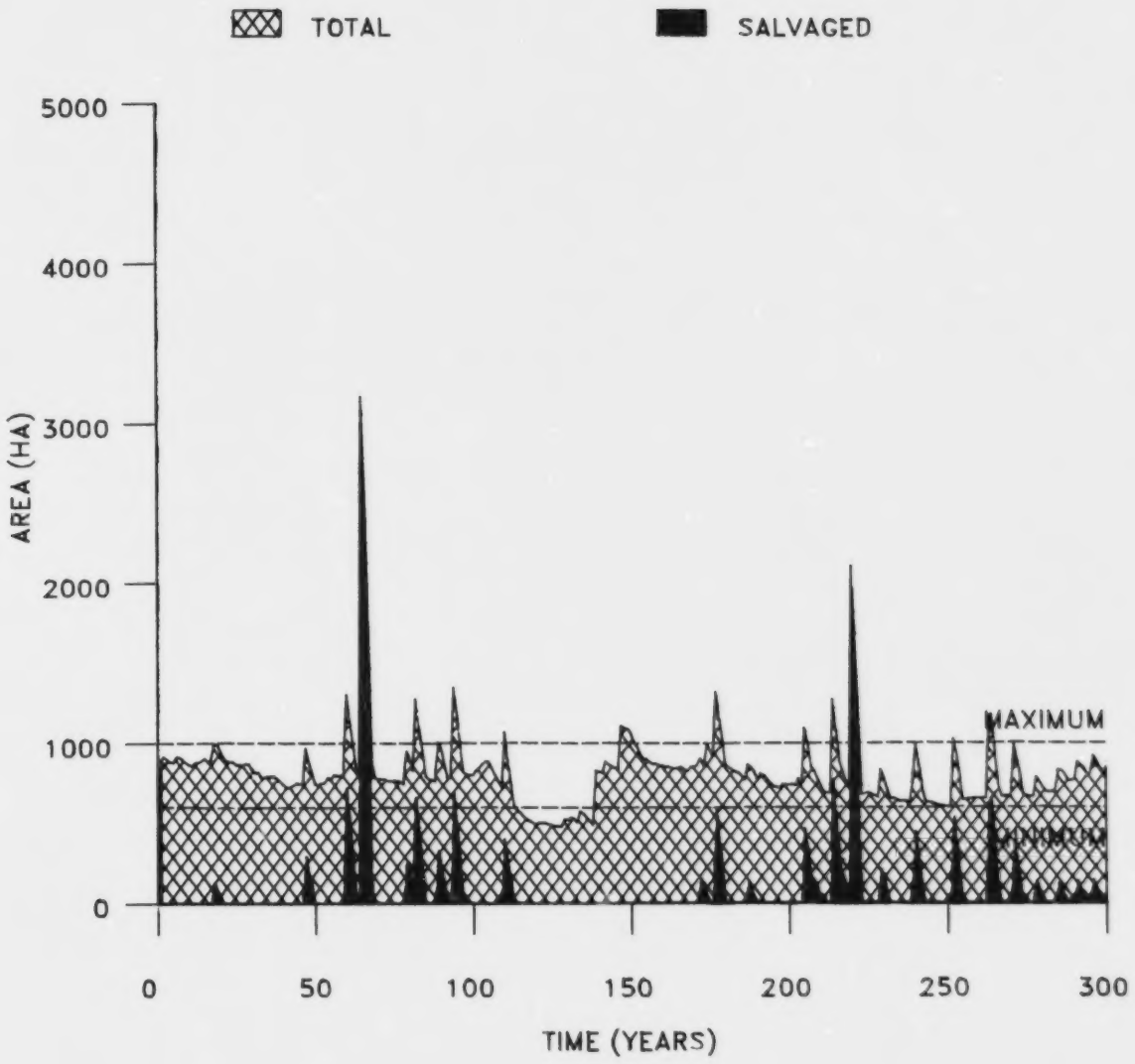

Figure 19. Test 5: annual area cut.

Test 6. Option 1 (No management).

In this test, it was assumed that no management would be implemented on the forest and that no fire-damaged wood would be salvaged. There was thus a rapid initial increase in the inventory of the forest that lasted for 50-60 years followed by a sharp decline due to the bad fire year in 64 and a more gradual decline over the next 100 years (Figure 20).

In the initial forest (see the age-class distribution for year 0 in Figure 9), all of the stands are 100 years old or less. These will continue to put on increment for at least the next 50 years. After year 50, an increasing proportion of the stands in the forest will be greater than 150 years old and will, therefore, be declining in volume (see Figure 1). The age-class distribution, even in year 300 (Figure 21), showed little evidence of the expected reverse J-shaped pattern so that the test was repeated with the annual fire loss fixed at 0.477 per cent of the area (Test 6A). This did result in the expected pattern becoming established for the first 90 years (Figure 21) but it appears that the simulation would have to be run for a considerably longer period before the forest would reach a steady state. Figure 20 shows that, for the forest with a constant annual fire loss, the inventory tends to follow a sine-wave type of curve with declining amplitude over time. This would presumably decay to a constant level eventually.

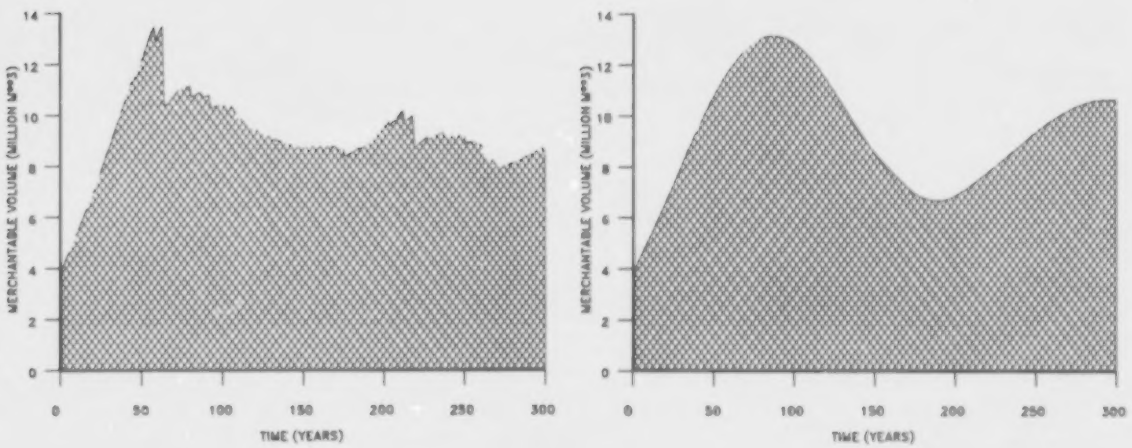

Figure 20. Test 6: residual forest inventory with variable annual burn (left) and constant annual burn (right).

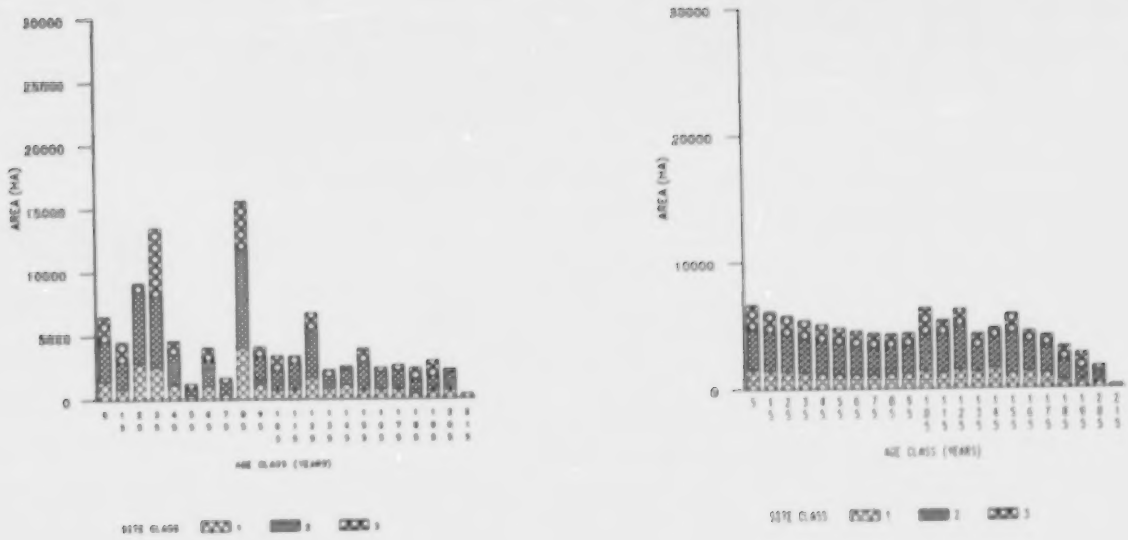

Figure 21. Test 6: age-class distribution at the end of year 300 with variable annual burn (left) and constant annual burn (right).

Test 7. Option 2 (All stands harvested at age 150 years).

The minimum level of management (Option 2) has been implemented in this test. Stands 150 years old or greater are harvested in the first year and the remaining stands as they reach 150 years. Because the oldest stands in the initial forest are in the 105-year age class (Figure 22), no harvesting is done during the first 40 years (Figure 23: there is some salvage harvesting earlier but because of the vertical scale that is used, this does not show). Between years 50 and 150 there is a reasonably steady annual harvest and then another 40-50 year period of negligible annual harvests (any wood that is harvested comes from areas that were burnt during the first 40 years). The very large harvest (3.1 million m^3) in year 214 comes from the extensive area that was burnt in year 64. The age-class distributions over time (Figure 22), and the inventory of the residual forest (Figure 24), also reflect the harvesting pattern. The average annual cut was 99 579 m^3 from an average of 525 ha.

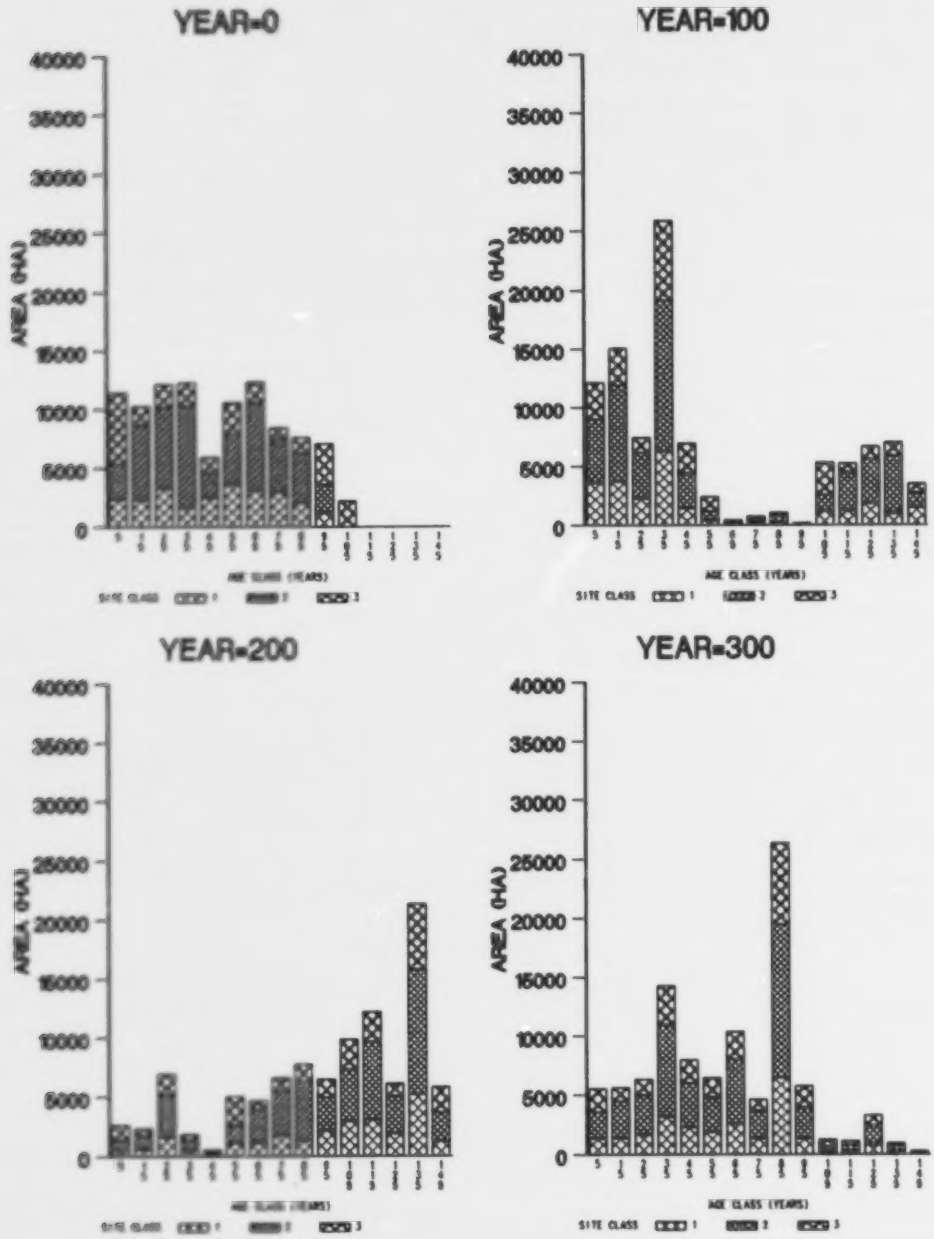

Figure 22. Test 7: age-class distribution histograms.

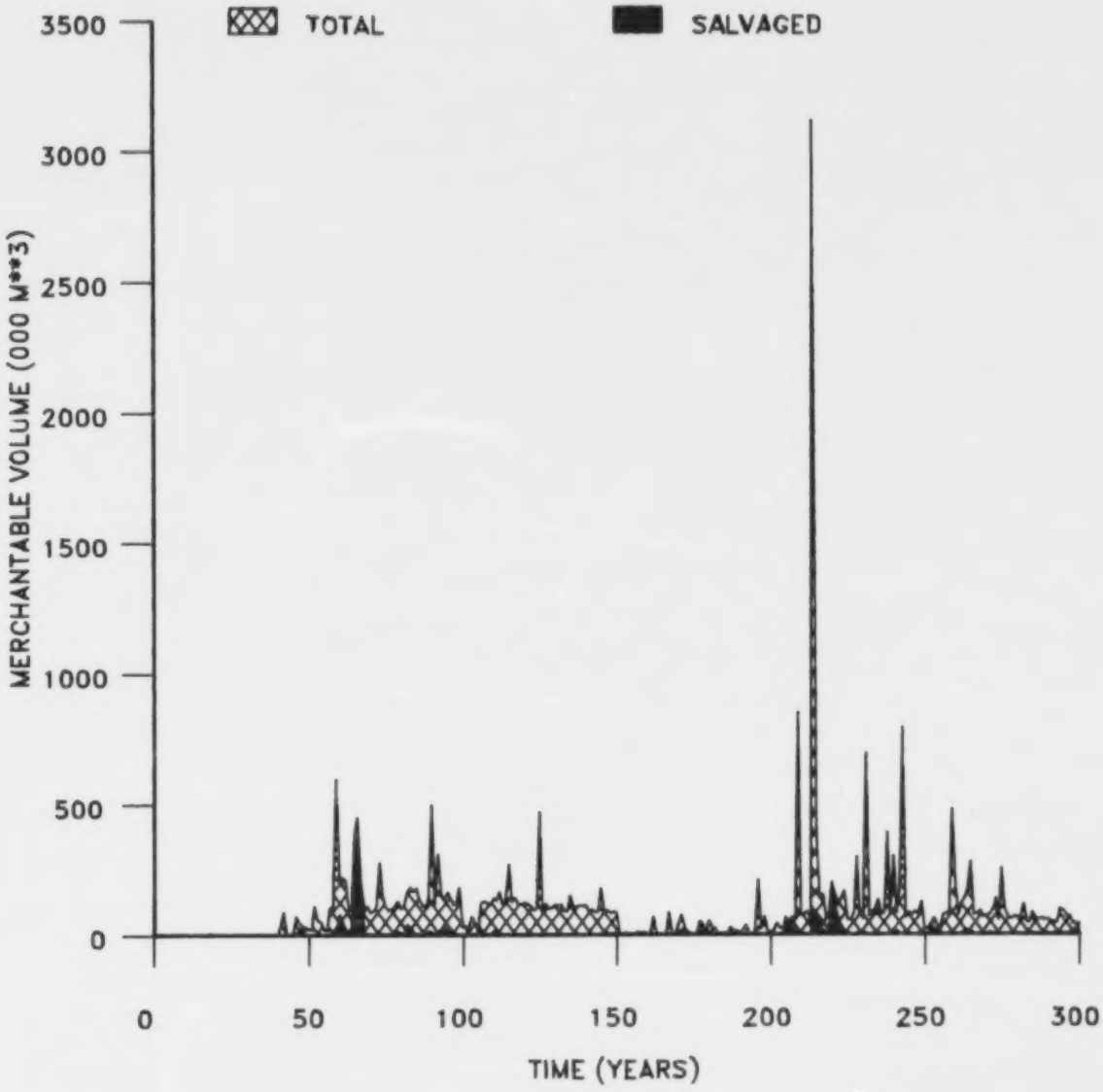

Figure 23. Test 7: annual cut.

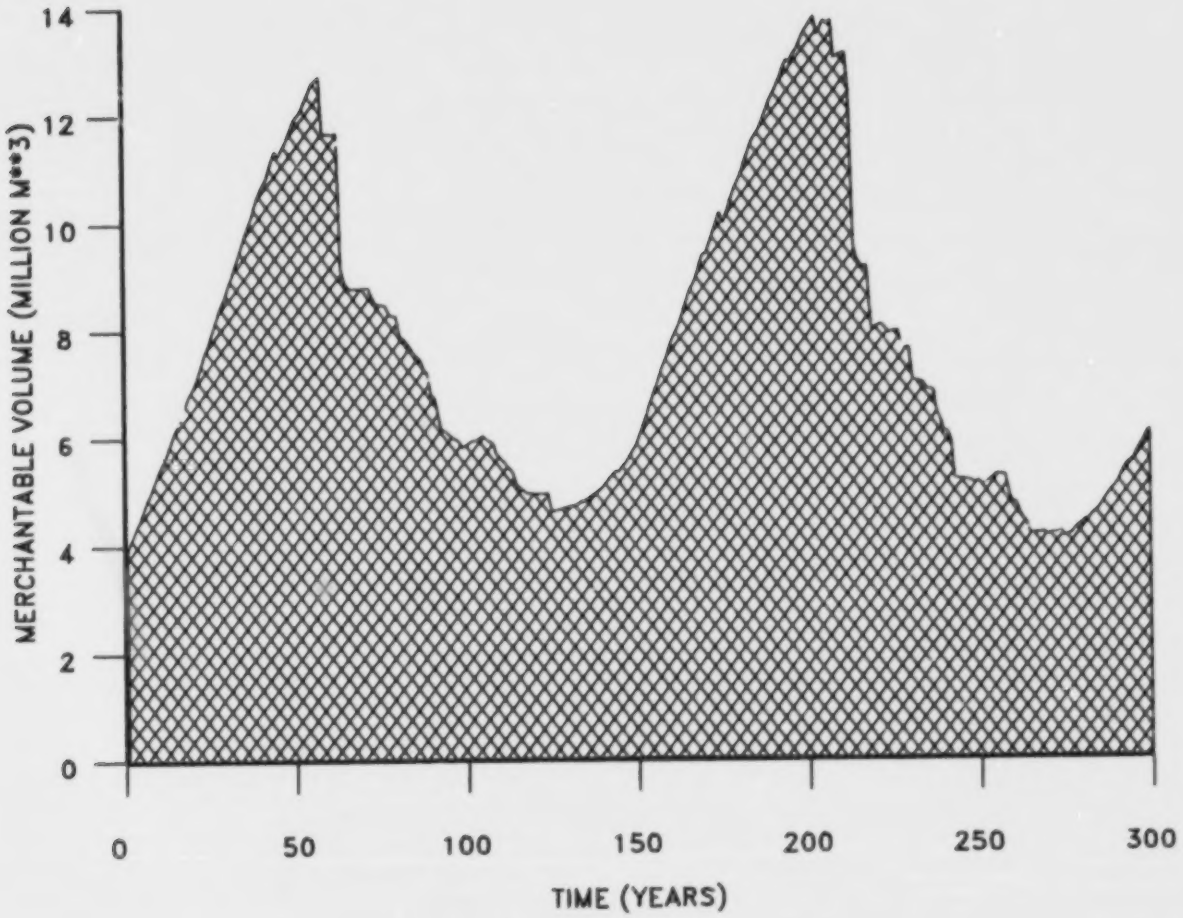

Figure 24. Test 7: residual forest inventory.

Test 8. Option 3 (Stands harvested at age of maximum MAI).

Test 8 demonstrates a slightly more advanced form of management where "old-growth" stands are harvested at age 150 years (as in Test 7) but otherwise the rotation for each site class is fixed at the age of maximum mean annual increment (100 years for site class 1, 120 years for site class 2, and 135 years for site class 3). Apart from the first six years, when there were no stands of harvestable age, there is a continuous flow of harvested wood (Figure 25) and, although the amount fluctuates from year to year, these fluctuations are not as noticeable as in Test 7. The average yield (122 014 m^3/yr) is also higher but this is obtained from a much lower average inventory (5.0 million m^3 as opposed to 7.6 million m^3 for Test 7).

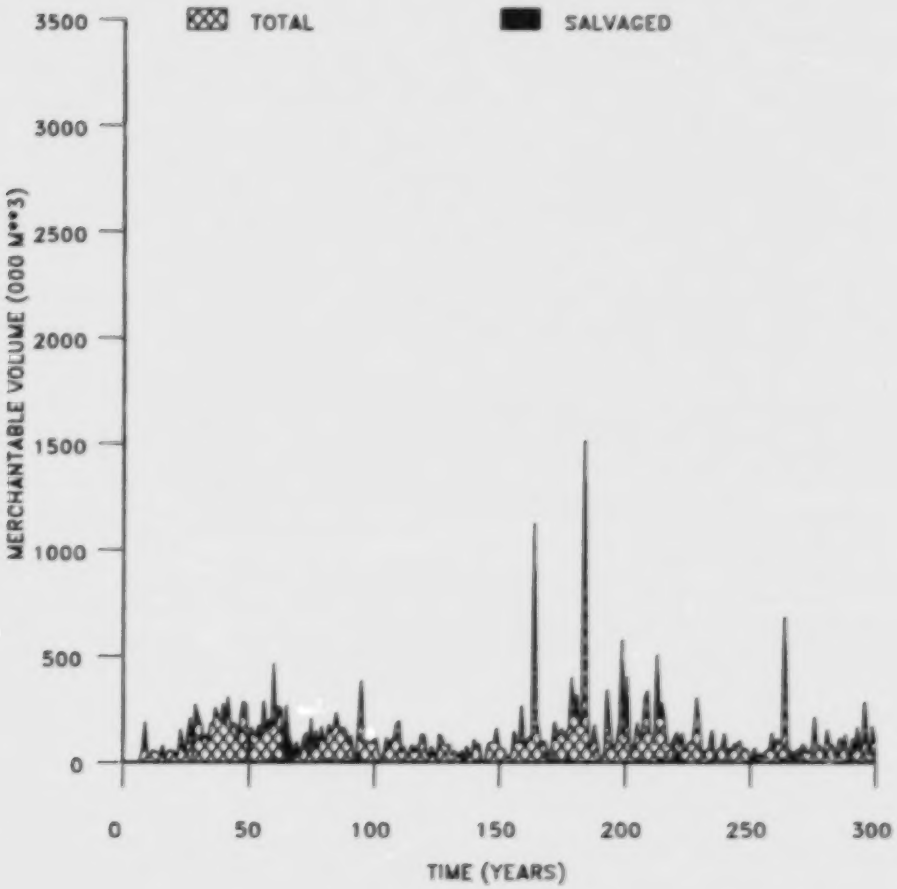

Figure 25. Test 8: annual cut.

Test 9. Option 5 (Annual harvest = 120 000 m^3).

The results obtained in Test 8 indicate that the basic forest is able to sustain an annual cut of approximately 122 000 m^3. Test 9 is identical to Test 1 except that the prescribed annual harvest was 120 000 m^3 and the range was changed to between 115 000 m^3 and 125 000 m^3. Figure 26 shows that this relatively small reduction in AAC is sustainable throughout the 300-year period. Although there is still considerable fluctuation in the inventory, mainly caused by the bad fire years (64 and 219), there is no evidence in Figure 27 of any decline: in fact, the final inventory (4 190 357 m^3) is some 700 000 m^3 greater than the final inventory in Test 1.

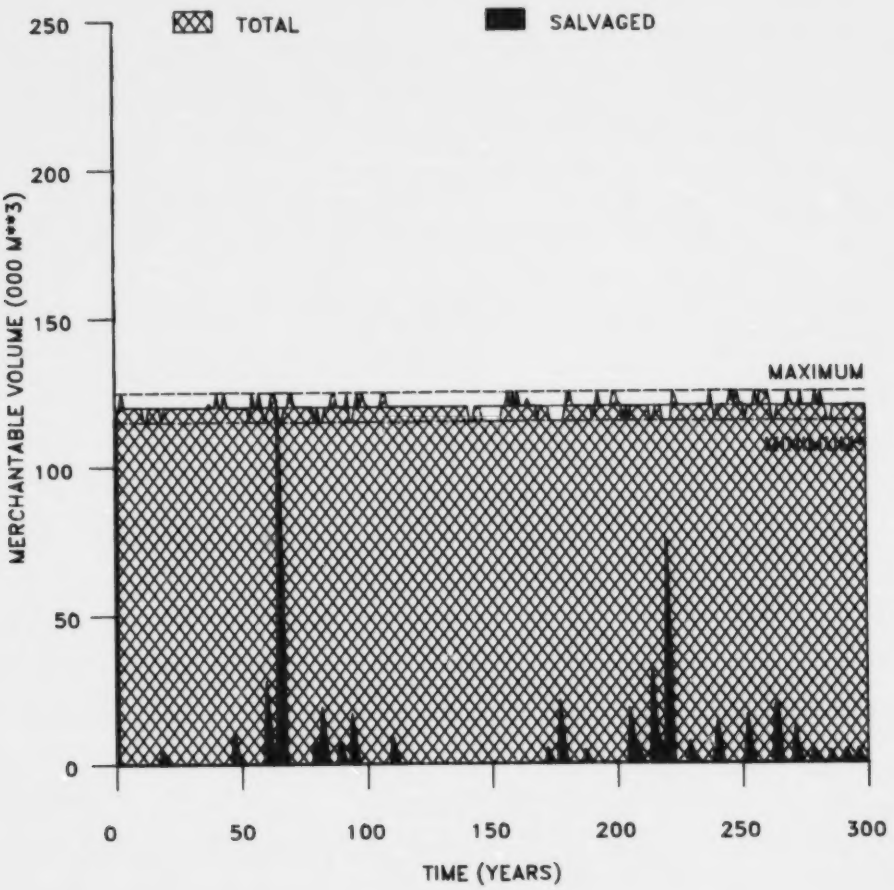

Figure 26. Test 9: annual cut.

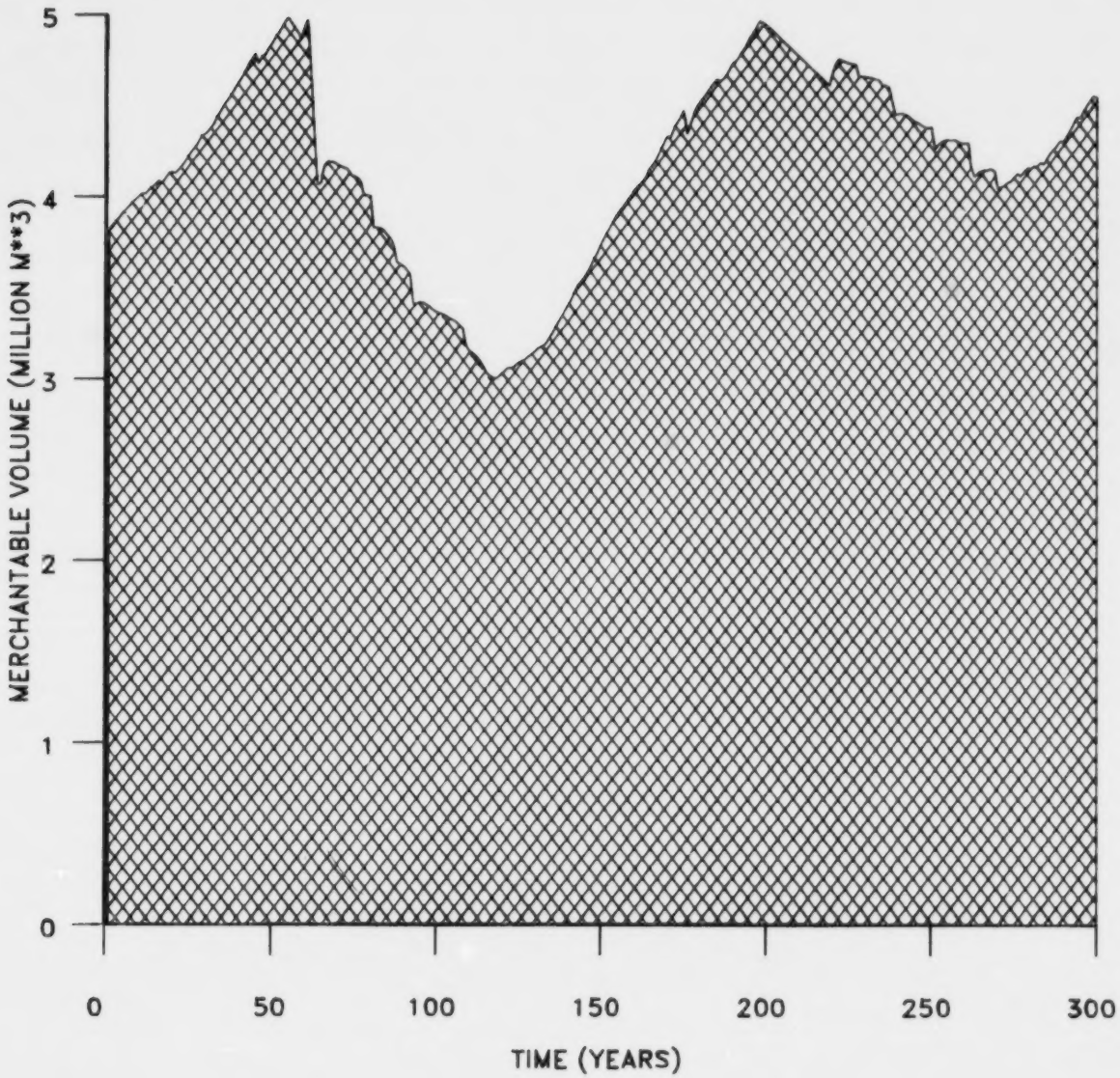

Figure 27. Test 9: residual forest inventory.

Test 10. Option 4 (Annual harvest = 120 000 m^3/ha).

This test simulates the final harvesting option (Option 4) in which the stands are selected for harvesting in order of declining merchantable volume. As in Test 9, the annual harvest was prescribed at a level of 120 000 m^3. This change in strategy does have a marked effect on the harvesting pattern (Figure 28). Once again, there is a 20-year shortfall period 50-60 years after the bad fires in year 64. There is also a shortfall, not experienced in previous tests, in years 285 and 286 that is apparently the result of the bad fire year, 219. Figure 29 shows the effect of the new strategy on the age-class distribution at 100-year intervals during the simulation. Because harvesting is concentrated in the high-volume, site class 1 and 2 stands a large proportion of the site class 3 stands are not harvested and begin to decline in volume after age 150 years. At year 100, for example, there are class 3 stands in all age classes to 205. By year 200, many of these stands have disappeared, either because their volume has declined to 0 (at about age 210), they have been burnt (the risk of fire rises after the stands reach 150 years - see Figure 3), or those stands containing more than 90 m^3/ha were harvested during the shortfall period between years 118 and 138. If it were not for the age restriction of 75 years, it is probable that more of the site class 1 stands would have been harvested as, after year 0, none of these stands are found above age class 75. The forest inventory (Figure 30) fluctuates considerably more than in Test 9 but the final inventory is approximately 2 million m^3 less.

Table 1 summarizes the results obtained for Tests 1-10.

Table 1. Summary of results for Tests 1 - 10: annual averages and final residual inventory.

Test	Average annual area (ha)				Average annual merchantable volume (m^3)						Final
								Fire loss			
No.	Burnt	Harvested	Salvaged	Total	Harvested	Salvaged	Total	Total	Salvageable	Growth	Inventory
1	477	806	95	901	118 996	2 864	121 860	14 000	2 886	129 553	3 486 832
2	477	758	95	853	117 722	3 098	120 820	15 151	3 128	133 045	3 835 994
3	477	857	98	955	118 340	2 415	120 756	11 775	2 426	124 782	3 069 597
4	477	1 570	95	1 666	49 030	1 128	50 158	5 421	1 128	41 807	1 140 067
5	477	770	95	865	118 337	2 931	121 268	14 447	2 956	131 171	3 817 639
6	476	0	0	0	0	0	0	44 419	0	60 887	9 201 624
6A	475	0	0	0	0	0	0	39 604	0	62 428	9 359 306
7	477	430	95	525	92 071	7 509	99 579	35 426	7 554	135 085	7 563 044
8	477	623	95	718	118 557	3 462	122 014	17 545	3 509	144 090	4 970 953
9	477	716	95	812	116 553	3 372	119 925	16 474	3 406	135 544	4 190 357
10	477	730	95	825	111 616	3 536	115 152	16 937	3 556	124 249	3 795 928

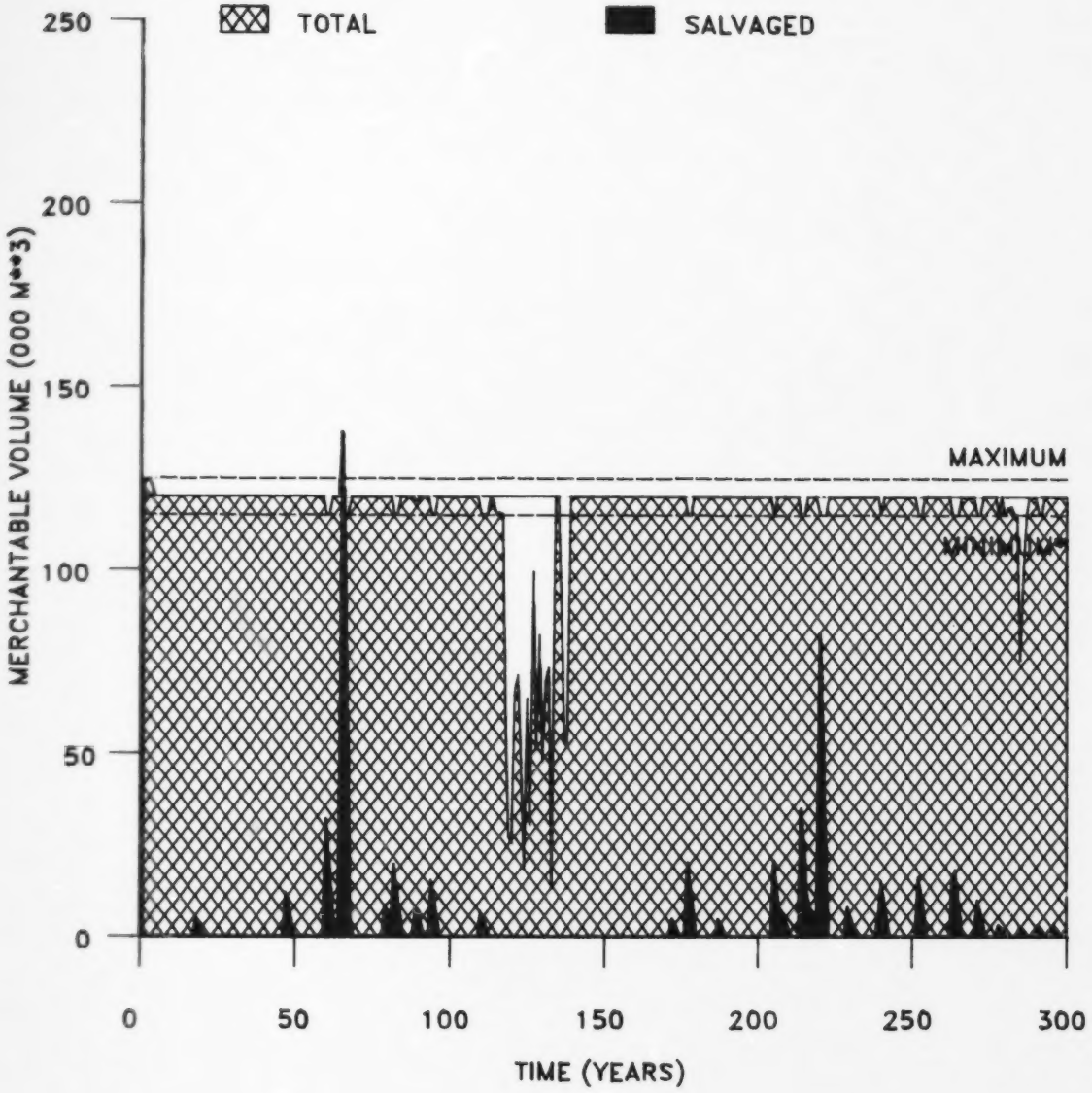

Figure 28. Test 10: annual cut.

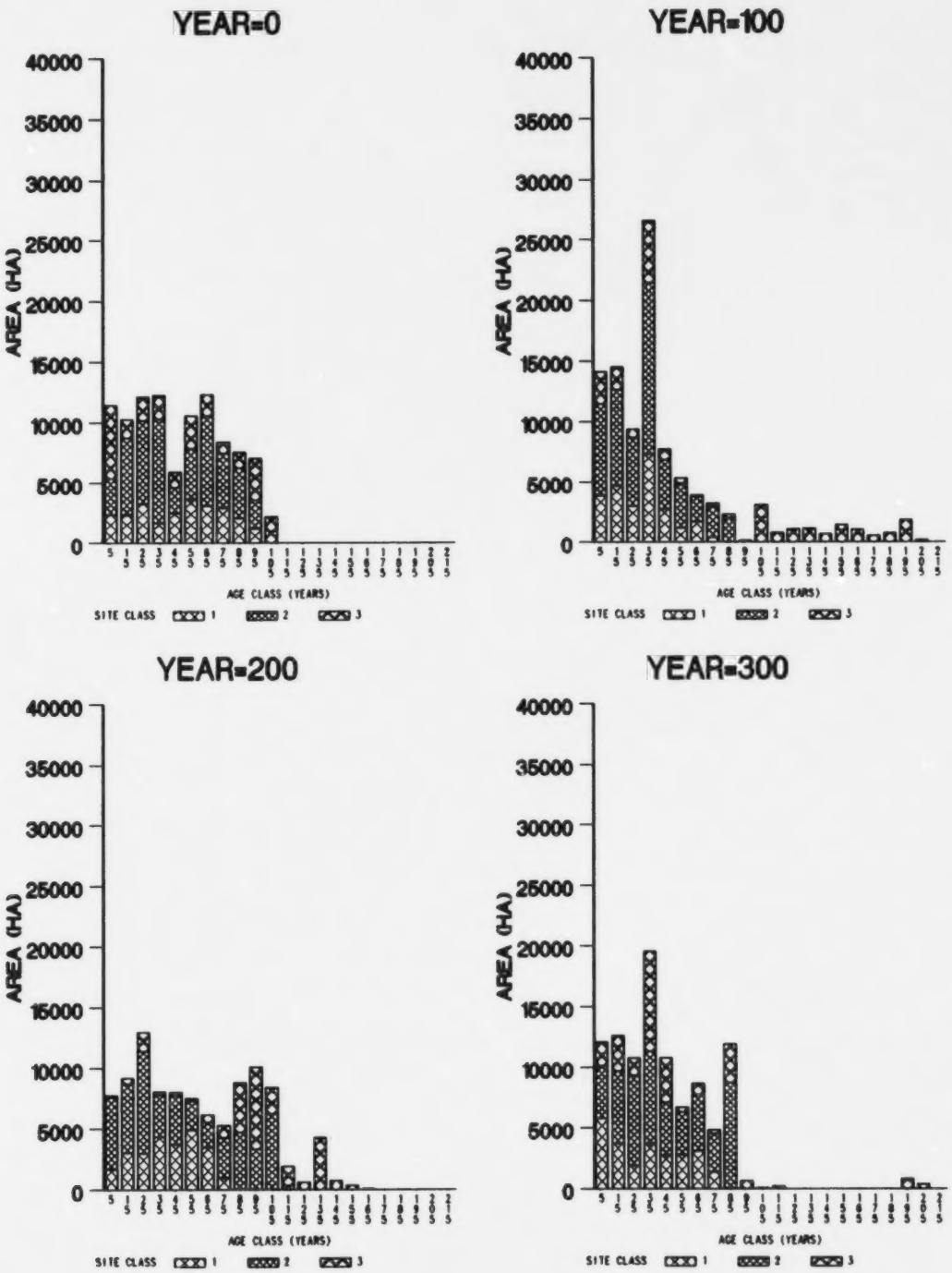

Figure 29. Test 10: age-class distribution histograms.

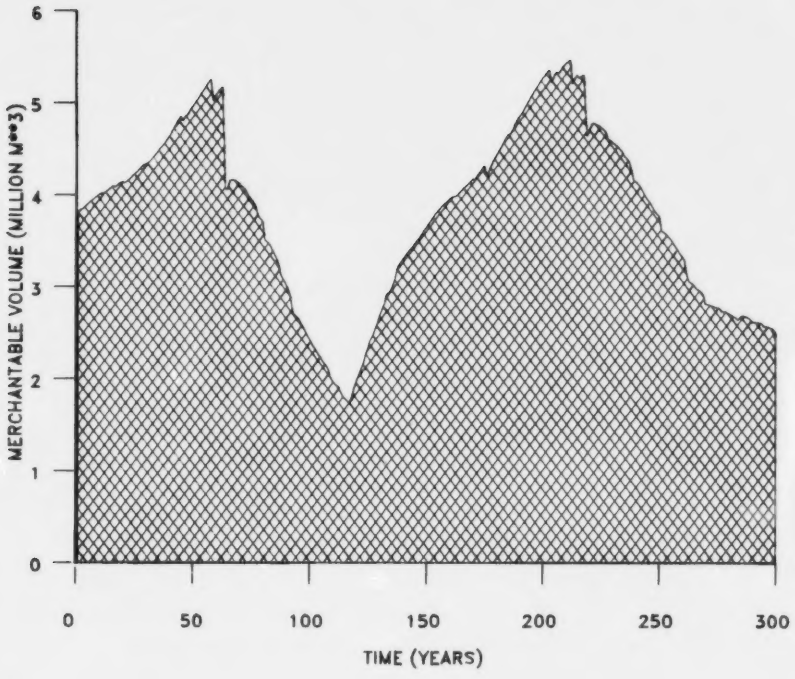

Figure 30. Test 10: residual forest inventory.

DISCUSSION AND CONCLUSIONS

The tests that have been described here give some idea of the types of question for which the model, FIRFOR, can provide answers and the types of problem that FIRFOR can help to resolve. The tests have not been exhaustive: no attempt has been made to test a range of values for each input variable, nor to test a variety of combinations of values for these variables in an attempt to obtain the optimum management strategy, i.e. that combination of management options and input values that maximizes long term sustainable yield. However, it does appear from the limited range of tests that have been undertaken that our hypothetical black spruce forest could supply approximately 122 000 m^3/year.

The model in its present form obviously has shortcomings. The forest that is used in the tests can contain only one forest type in up to three, rigidly assigned site classes. In theory, the model could be readily modified to permit many forest types by adding another "dimension" to the basic forest. Site index, instead of site class, could be used in the growth function for each forest type. The logical next step would be to derive the input data for the forest from a GIS database: as noted previously, this is one of the ultimate objectives of the model.

Although the model does allow for a number of forest management options, these all relate to the method of determining the annual harvest. It is assumed that, once a stand is harvested, burnt, or dies, it immediately regenerates naturally and its life cycle is repeated. Silvicultural treatments, such as planting, thinning or fertilization, cannot be tested, nor can regeneration with genetically improved growing stock or a different species be simulated. Some of these options were included in an earlier model developed at the Institute but were dropped from FIRFOR, largely because of a lack of supportive data. Once the necessary information on the growth response to the different treatments becomes available, these options could be included again in the model.

FIRFOR allows for two methods of simulating the area burnt each year: either a fixed amount or an amount drawn at random from a Weibull distribution that may be quite skewed. The latter is probably more realistic if the distribution of annual areas burnt is known for the region in which the forest is located and, perhaps more importantly, at the correct scale, i.e. for areas approximately equal to the area of the forest that is being studied. By and large, the area that is going to be burnt in any year cannot be forecast ahead of time, so that it could be argued that there is little point in simulating a variable amount: it is sufficient to work with an average (either by averaging a number of simulations or by using a fixed annual burnt area). Although a bad fire year cannot be predicted, it is useful to have some idea of what effects, both short term and long term, on annual harvest such disasters can have so that steps can be taken to lessen their impact. While on the subject of fire, one modification that should be made to FIRFOR is to impose a constraint on the proportion of the annual harvest that can consist of salvaged wood. In some of the tests (see e.g. Figures 5 and 26), in the year following the bad fire year 64, over 90 per cent of the harvest was comprised of fire-damaged wood. This wood most certainly would be unacceptable as mill furnish. Another constraint could easily be built into the model that would restrict the proportion of fire-damaged wood to, say, 25

per cent of the total harvest (the balance could be cut and held over for future use, could be cut in the following years, or not cut at all).

No attempt has been made to include in the model the effects of other damaging agents, such as insects and disease, although these were included in the earlier model that was noted previously. These agents, unlike fire, are to some extent predictable. Insect populations are cyclic and, once the onset of an epidemic has been detected, their effect on forest growth can be predicted and steps taken to lessen their impact. Pest modelling and the different strategies for combating pests are extremely complex and, at this stage, should probably be considered separately from forest management modelling as another component of the overall DSS. The results of a pest model could be included in a simplified form in a model such as FIRFOR.

In spite of shortcomings in its present form, FIRFOR can be used to provide valuable information to the forest manager on the effects of fire on long-term yield and to test different strategies for harvesting. A unique feature among forest management models is the ability to control the annual harvest by volume, with an area check, or by area, with a volume check. Refinements, based on practical requirements, will continue to be made.

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Reed, W.J.; Errico, D. 1985. Assessing the long-run yield of a forest stand subject to the risk of fire. Can. J. Forest Res. 15: 680-687.

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APPENDICES

APPENDIX I

This appendix gives a listing of the FORTRAN program for the FIRFOR model, a description of the input and output files (Table I-1), and a summary flow-chart that shows the inter-relationships among the program segments and the input/output files. Finally, using Test 1 as an example, a listing is given of the output files: FORMOD.OUT and AGECLA.TAB.

Explanations have been interspersed in the program listing at appropriate intervals to aid the reader in understanding how the program works. Although not exhaustive, these should enable the user to check the validity of the program or to make modifications should he so desire. The program has been written in FORTRAN 77 for a Digital Equipment Corporation VAX/785 mini-computer using the VAX/VMS V4.3 operating system. Copies of the program may be obtained by sending an eight-track tape to:

Petawawa National Forestry Institute
Canadian Forestry Service
Government of Canada
CHALK RIVER, Ontario
K0J 1J0

Attention: Dr. R.M. Newnham

```
      DIMENSION A(3,225),MAGE(3),MHA(3),MHO(3),AR(3),AREG(3),HSALV(5),
     1AV(12),ASALV(5)
      VIRTUAL GHA(3,225),P(3,225),EP(3,225),V(3,225),VHA(3,225)
      INTEGER*4 ISEED,JSEED,IOUT(12),JOUT(12),JVOL
      BYTE YN,YNE,YNP,YNR,YNT,YNY,YNH,INFIL(20),TEST(8),TITLE(45),
     1YES,YNS,YSAS
      DATA YES/'Y'/
```

The dimensions are fixed by the number of site classes (3) in Plonski's black spruce yield tables, the maximum age (225) that black spruce stands could attain in the model, and the number of options (5) for the length of the salvaging period. The dimension (12) is for the output variables. INFIL, TEST, and TITLE are character variables that are used to indicate the file on which the initial forest may be stored, the test number, and a brief description of the test, respectively. Provided that appropriate changes are made to the program (mainly to DO and implied DO loops), the dimensions of the variables may be increased but should not be decreased.

```
      OPEN(UNIT=2,NAME='FORMOD.INP',FORM='FORMATTED',STATUS='NEW')
      OPEN(UNIT=3,NAME='FORMOD.OUT',FORM='FORMATTED',STATUS='NEW')
      OPEN(UNIT=11,NAME='SUBR.TXT',FORM='FORMATTED',STATUS='OLD',
     1READONLY)
```

A description of these, and other, files is given in Table 1.

```
      WRITE(5,5)
      WRITE(2,5)
5     FORMAT(///' Do you want the results from this test plotted using'/
     1'   SAS/GRAPH (Y/N)? ',$)
      READ(5,140) N,YSAS
      WRITE(2,145) YSAS
      IF(YSAS.EQ.YES) OPEN(UNIT=10,NAME='SGRAPH.DAT',FORM='FORMATTED',
     1STATUS='NEW')
      ER=1.E-10
      WRITE(5,10)
      WRITE(2,10)
10    FORMAT(///' ENTER random number seed (<2147483647):'/)
      READ(5,*) ISEED
      WRITE(2,*) ISEED
      JSEED=ISEED
      WRITE(5,20)
      WRITE(2,20)
20    FORMAT(///' GENERATE INITIAL FOREST'//
     1' Do you want:'/
     2'    1.  a UNIFORM DISTRIBUTION of area by one-year age'/
     3'        classes'/
     4'    2.  a RANDOM DISTRIBUTION of area by one-year age'/
     5'        classes'/
     6'    3.  a previously generated forest?'//
     7' ENTER 1, 2 or 3:  ',$)
      READ(5,*) IND
      WRITE(2,*) IND
      IF(IND.EQ.3) GO TO 120
      WRITE(5,30)
      WRITE(2,30)
30    FORMAT(//' ENTER number of site classes (Max. = 3):  ',$)
      READ(5,*) IC
      WRITE(2,*) IC
      WRITE(5,40)
      WRITE(2,40)
40    FORMAT(//' For each site class, ENTER oldest age class present and
     1'/'   total area (ha), e.g. 140,125000'/)
      DO 60 I=1,IC
      WRITE(5,50) I
      WRITE(2,50) I
```

```
50    FORMAT(' SITE CLASS',I2,': ',$)
      READ(5,*) MAGE(1),AR(I)
60    WRITE(2,*) MAGE(I),AR(I)
      IF(IND.EQ.2) GO TO 80
      DO 75 I=1,IC
      F=MAGE(I)
      F=AR(I)/F
      DO 70 J=1,MAGE(I)
70    A(I,J)=F
      K=MAGE(I)+1
      DO 75 J=K,225
      A(I,J)=0.
75    V(I,J)=0.
      GO TO 110
```

For the uniform distribution of age classes (IC=1), within each site class each one-year age class is assigned an area, A(I,J), that is equal to the total area for the site class, AR(I), divided by the maximum age, MAGE(I). All A(I,J) for J > MAGE(I) are assigned a 0 value.

```
80    DO 105 1=1,IC
      F=0.
      DO 90 J=1,MAGE(I)
      G=RAN(ISEED)
      F=F+G
90    V(I,J)=G
C***  V(I,J) is used for temporary storage.
      G=AR(I)/F
      DO 100 J=1,MAGE(I)
100   A(I,J)=G*V(I,J)
      K=MAGE(I)+1
      DO 105 J=K,225
      A(I,J)=0.
105   V(I,J)=0.
```

For the random age-class distribution (IC=2), the V(I,J) array is used for temporarily storing the random numbers. F is the sum of these random numbers for the site class and G is the area divided by this sum. The area assigned to each one-year age class is thus equal to: AR(I)r/F, where r is the random number for the age class (0 < r < 1).

```
110   CALL VOLUME(IC,IV,YNY,ER,VHA,GHA)
C***  Subroutine VOLUME generates yield values and assigns merchantable
C***     volume (m**3) and growth rate (m**3/ha) to each age class in
C***     each site class
      DO 115 I=1,IC
      DO 115 J=1,MAGE(I)
```

```
      IF(VHA(I,J).NE.ER) GO TO 112
      V(I,J)=ER
```

Age classes that are present in the forest, but which contain no merchantable wood, have their volume set equal to a very small number, ER (0.1E-10), rather than 0. If this was not done, the model would identify these age classes as requiring regeneration and would reset their age to 0.

```
      GO TO 115
112   V(I,J)=A(I,J)*VHA(I,J)
115   CONTINUE
      GO TO 180
120   WRITE(5,130)
      WRITE(2,130)
130   FORMAT(///' INPUT file name on which initial forest data are store
     1d:'/)
      READ(5,140) N,INFIL
140   FORMAT(Q,45A1)
      WRITE(2,145) (INFIL(I),I=1,N)
145   FORMAT(10X,45A1)
      INFIL(N+1)='0
      OPEN(UNIT=9,NAME=INFIL,FORM='FORMATTED',STATUS='OLD',READONLY)
      READ(9,146) DATE,ITEST,(TEST(I),I=1,ITEST)
146   FORMAT(F8.4,I4,4X,8A1)
      WRITE(5,147) (INFIL(I),I=1,N),(TEST(I),I=1,ITEST),DATE
      WRITE(2,147) (INFIL(I),I=1,N),(TEST(I),I=1,ITEST),DATE
147   FORMAT(//' File: ',<N>A1,4X,'Test No.:',<ITEST>A1,4X,'Date:',F8.4
     1//'      Is this the correct file (Y/N)? ',$)
      READ(5,140) N,YN
      WRITE(2,145) YN
      IF(YN.NE.YES) GO TO 120
      READ(9,150) IC,IV,(MAGE(I),I=1,IC)
150   FORMAT(8I4)
      CALL VOLUME(IC,IV,YNY,ER,VHA,GHA)
      READ(9,160) ISALV,(HSALV(I),I=1,5)
160   FORMAT(I4,5F11.2)
      DO 170 I=1,IC
      K=MAGE(I)+1
      DO 165 J=K,225
      A(I,J)=0.
165   V(I,J)=0.
      READ(9,160) K,AR(I)
      DO 170 J=1,MAGE(I)
170   READ(9,160) K,A(I,J),V(I,J)
      CLOSE(UNIT=9)
180   CALL FEIRE(IC,IV,IAF,IFR,YNF,PF,FP,WB,WC,AR)
C***  For each site class, subroutine FEIRE assigns a relative
C***     proportion of the area in each age class that will be lost to
```

```
C***     fire.  The proportion of the total area that is lost to fire
C***     each year is also defined as either a specified constant
C***     amount or drawn at random from a specified Weibull Distributio
      CALL MANAGE(IC,IH,MHA,MHO,MINA,AAC,HMIN,PSALV,ISALV,FSALV,
     1YNH,COMPF,IAV,ALO,AMN,AUP,VLO,VUP)
C***  Subroutine MANAGE inputs one of five management options
C***     (including no management).  The conditions under which
C***     salvaging of burnt timber can be undertaken are also input
      WRITE(5,190)
      WRITE(2,190)
190   FORMAT(///' ENTER Test No. (Max. of 8 characters):'/)
      READ(5,140) ITEST,TEST
      WRITE(2,145) (TEST(I),I=1,ITEST)
      WRITE(5,195)
      WRITE(2,195)
195   FORMAT(//' ENTER date in metric format, (e.g. 85.1122 for'/
     1'    22 NOV: 1985):  ',$)
      READ(5,*) DATE
      WRITE(2,*) DATE
      WRITE(5,210)
      WRITE(2,210)
210   FORMAT(/' ENTER Title (Max. of 45 characters):'/)
      READ(5,140) NTIT,TITLE
      WRITE(2,145) (TITLE(I),I=1,NTIT)
      WRITE(3,220) (TEST(I),I=1,ITEST),TITLE
220   FORMAT(1H1,10X,<ITEST>A1,'.  ',45A1)
      GO TO (222,224,226),IV
222   WRITE(3,223)
223   FORMAT(//20X,'Forest Type: BLACK SPRUCE'/)
      GO TO 228
224   WRITE(3,225)
225   FORMAT(//20X,'Forest Type: RED PINE'/)
      GO TO 228
226   WRITE(3,227)
227   FORMAT(//20X,'Forest Type: RESERVED FOR FUTURE USE'/)
228   LINES=5
      IYR=0
      WRITE(5,230)
      WRITE(2,230)
230   FORMAT(//' Do you want a tabular summary of the initial'/
     1'    forest (Y/N)?  ',$)
      READ(5,140) N,YNT
      WRITE(2,145) YNT
      IF(YNT.NE.YES) GO TO 260
      OPEN(UNIT=4,NAME='AGECLA.TAB',FORM='FORMATTED',STATUS='NEW')
      WRITE(5,240)
      WRITE(2,240)
240   FORMAT(// ' Area and volume are printed for each age class.'/
     1'    ENTER number of years in each age class:  ',$)
```

```
      READ(5,*) ICLASS
      WRITE(2,*) ICLASS
      WRITE(5,250)
      WRITE(2,250)
250   FORMAT(//' At what intervals during the run do you want age-class'
     1/'   distribution tables printed?'/
     2' ENTER the number of years: ',$)
      READ(5,*) IINT
      WRITE(2,*) IINT
      KLINES=60
      CALL TABLE(IC,IYR,ITEST,TEST,DATE,KLINES,ICLASS,A,V)
C***  Subroutine TABLE produces age-class distribution tables
260   WRITE(5,270)
      WRITE(2,270)
270   FORMAT(//' Do you want the initial and periodic age-class'/
     1'   distributions plotted (Y/N)?  ',$)
```

The response to this question must be 'Y' if the age-class histograms are to be plotted using either Institute software or SAS/GRAPH.

```
      READ(5,140) N,YNP
      WRITE(2,145) YNP
      IF(YNP.NE.YES) GO TO 300
      WRITE(5,280)
      WRITE(2,280)
280   FORMAT(//' ENTER number of years in each age class:  ',$)
      READ(5,*) JCLASS
      WRITE(2,*) JCLASS
      WRITE(5,290)
      WRITE(2,290)
290   FORMAT(//' At what intervals during the run do you want the'/
     1'    age-clss distributions plotted?'/
     2' ENTER number of years:  ',$)
      READ(5,*) JINT
      WRITE(2,*) JINT
      OPEN(UNIT=1,NAME='AGECLA.PLT',FORM='FORMATTED',STATUS='NEW')
      IF(YSAS.EQ.YES) OPEN(UNIT=12,NAME='SHIST.DAT',FORM='FORMATTED',
     1STATUS='NEW')
      AMAX=0.
      CALL PLOTAC(IC,IYR,ITEST,TEST,DATE,JCLASS,A,AMAX,YSAS)
300   WRITE(3,310)
310   FORMAT(//10X,'I N I T I A L   F O R E S T'///
     120X,'Site      Area    Merchantable'/
     220X,'class     (ha)    volume (m**3)'//)
      LINES=LINES+8
      ATOT=0.
      VTOT=0.
      DO 340 I=1,IC
```

```
      ATOT=ATOT+AR(I)
      SV=0.
      DO 320 J=1,MAGE(I)
320   SV=SV+V(I,J)
      VTOT=VTOT+SV
      IOUT(1)=AR(I)+.5
      IOUT(2)=SV+.5
      WRITE(3,330) I,IOUT(1),IOUT(2)
330   FORMAT(20X,I3,I12,I13)
340   LINES=LINES+1
      IOUT(1)=ATOT+.5
      IOUT(2)=VTOT+.5
      WRITE(3,350) IOUT(1),IOUT(2),JSEED,ISEED
350   FORMAT(/20X,'TOTAL',I10,I13////20X,'Random number seeds:'//
     130X,'Initial:',I11/30X,'At start of simulation run:',I11///)
      LINES=LINES+11
      IF(IAV.EQ.0.) GO TO 358
      IOUT(1)=AMN
      IOUT(2)=ALO
      IOUT(3)=AUP
      IOUT(4)=VLO
      IOUT(5)=VUP
      IOUT(6)=AAC
      IF(IAV.EQ.1) WRITE(3,354) (IOUT(I),I=1,5)
354   FORMAT(////20X,'Annual harvest is controlled by AREA.'//
     125X,'Scheduled annual harvest (ha) =',I8/
     225X,'   Range (ha)                 =',I8,' -',I8/
     325X,'Volume range (m**3)           =',I8,' -',I8//
     420X,'The scheduled area will be harvested each year, provided'/
     525X,'that the harvested volume falls within the specified'/
     625X,'range. If necessary, the area will be adjusted until'/
     725X,'the volume falls within its range'///)
      IF(IAV.EQ.2) WRITE(3,356) IOUT(6),IOUT(4),IOUT(5),IOUT(2),IOUT(3)
356   FORMAT(////20X,'Annual harvest is controlled by VOLUME.'//
     125X,'Scheduled annual harvest (m**3) =',I8/
     225X,'   Range (m**3)                 =',I8,' -',I8/
     325X,'Area range (ha)                 =',I8,' -',I8//
     420X,'The scheduled volume will be harvested each year, provided'/
     525X,'that the harvested area falls within the specified'/
     625X,'range. If necessary, the volume will be adjusted until'/
     725X,'the area falls within its range'///)
358   WRITE(5,360)
      WRITE(2,360)
360   FORMAT(///' At what interval do you want summary results printed'
     1'   during the simulation run?'/
     2' ENTER the number of years:  ',$)
      READ(5,*) KINT
      WRITE(2,*) KINT
      WRITE(5,380)
```

```
      WRITE(2,380)
380   FORMAT(//' Do you want the results (residual volume, harvest,'/
     1'   growth, etc.) plotted over time (Y/N):  ',$)
```

The response need only be 'Y' if plotting is to be done using Institute software.

```
      READ(5,140) N,YNR
      WRITE(2,145) YNR
      WRITE(5,382)
      WRITE(2,382)
382   FORMAT(//' Do you want to save the final state of the'/
     1'   forest (Y/N)?  ',$)
      READ(5,140) N,YNS
      WRITE(2,145) YNS
      WRITE(5,390)
      WRITE(2,390)
390   FORMAT(///' ENTER number of years for this simulation run:  ',$)
      READ(5,*) NYR
      WRITE(2,*) NYR
      CLOSE(UNIT=2)
      IF(YNR.NE.YES) GO TO 400
      OPEN(UNIT=2,NAME='FORRES.PLT',FORM='FORMATTED',STATUS='NEW')
      WRITE(2,395) (TITLE(I),I=1,NTIT),(TEST(I),I=1,ITEST),DATE
395   FORMAT(1X,<NTIT>A1/' TEST NO.: ',<ITEST>A1/' DATE:',F8.4)
400   DO 415 I=1,5
      AV(I)=0.
      IF(IND.NE.3) HSALV(I)=0.
415   JOUT(I)=0
      DO 420 I=6,12
      AV(I)=0.
420   JOUT(I)=0
      LINES=60
      JLINES=0
      JVOL=VTOT
      NPER=0
```

The next statement marks the start of the DO-loop that simulates the growth, fire occurence, and harvesting of the forest year by year.

```
      DO 580 N=1,NYR
      IF(IAE.EQ.2) PE=WB*(-ALOG(1.-RAN(ISEED)))**(1./WC)
C***  PE is the proportion of the total area that will be burnt in
C***     year N
      VESALV=0.
      VELOSS=0.
      VGROW=0.
      AFIR=0.
```

```
      VHARV=0.
      VSALV=0.
      VCUT=0.
      ASUM=0.
      SALVA=0.
      AHARV=0.
      DO 421 I=1,3
      DO 421 J=1,225
421   P(I,J)=0.
      CALL HARV(IC,IH,MHA,MHO,ER,AAC,VHARV,HSALV,A,V,P,AREG,VHA,GHA,
     1VSALV,YNH,COMPF,MINA,HMIN,ASUM,ASALV,SALVA,AHARV,IAV,ALO,AMN,AUP,
     2VLO,VUP)
C***  Subroutine HARV determines the volumes to be harvested in each
C***     age class of each site class according to the specified
C***     management option
C*** Calculate mortality:
      G=1.
      IF(IFR.EQ.1) GO TO 426
      K=0
      G=0.
      DO 422 I=1,IC
      DO 422 J=1,225
      IF(A(I,J).LE.0.) GO TO 422
      G=G+FP(I,J)*A(I,J)
422   CONTINUE
      G=ATOT/G
```

If IFR = 2, i.e. the proportion of the total area burnt in any year varies among age classes (see Figure 3), G is the total area of the forest divided by the sum of the products of the relative proportion and the area of each age class.

```
426   DO 430 I=1,IC
      DO 430 J=1,225
      IF(VHA(I,J).LE.0.) GO TO 428
      IF(V(I,J).EQ.ER) GO TO 430
C***  Calculate natural mortality:
      IF(VHA(I,J)+GHA(I,J).GE.ER) GO TO 428
```

Natural mortality occurs when the projected volume, one year hence, of an age class is less than 0.1E-10. AREG(I) is the area of site class I that will be regenerated in the current year.

```
      AREG(I)=AREG(I)+A(I,J)
      A(I,J)=0.
      V(I,J)=ER
      GO TO 430
C***  Calculate fire losses:
428   H=PF*FP(I,J)*G
```

For each site class - age class combination, H is the proportion of the area that will be burnt.

```
      VH=H*V(I,J)
      VFLOSS=VFLOSS+VH
      V(I,J)=V(I,J)-VH
      VH=A(I,J)*H
      A(I,J)=A(I,J)-VH
      AREG(I)=AREG(I)+VH
      AFIR=AFIR+VH
430   CONTINUE
      IF(YNH.NE.YES) GO TO 480
      IF(PF.LT.FSALV) GO TO 480
      VFSALV=VFLOSS*PSALV
      AFSALV=AFIR*PSALV
C***  Calculate volume of salvageable wood and proportionally assign
C***     it to succeeding years:
      GO TO (440,450,460,470),ISALV
440   HSALV(1)=HSALV(1)+VFSALV
      ASALV(1)=ASALV(1)+AFSALV
      GO TO 480
450   HSALV(1)=HSALV(1)+VFSALV*.6666667
      HSALV(2)=HSALV(2)+VFSALV*.3333333
      ASALV(1)=ASALV(1)+AFSALV*.6666667
      ASALV(2)=ASALV(2)+AFSALV*.3333333
      GO TO 480
460   HSALV(1)=HSALV(1)+VFSALV*.5
      HSALV(2)=HSALV(2)+VFSALV*.3333333
      HSALV(3)=HSALV(3)+VFSALV*.1666667
      ASALV(1)=ASALV(1)+AFSALV*.5
      ASALV(2)=ASALV(2)+AFSALV*.3333333
      ASALV(3)=ASALV(3)+AFSALV*.1666667
      GO TO 480
470   HSALV(1)=HSALV(1)+VFSALV*.5
      HSALV(2)=HSALV(2)+VFSALV*.25
      HSALV(3)=HSALV(3)+VFSALV*.125
      HSALV(4)=HSALV(4)+VFSALV*.125
      ASALV(1)=ASALV(1)+AFSALV*.5
      ASALV(2)=ASALV(2)+AFSALV*.25
      ASALV(3)=ASALV(3)+AFSALV*.125
      ASALV(4)=ASALV(4)+AFSALV*.125
480   VRES=0.
C***  'Grow' the forest for one year:
      DO 500 I=1,IC
      IF(IH.EQ.1.OR.IH.GT.3) L=224
      IF(IH.EQ.2.OR.IH.EQ.3) L=MHA(I)-1
      DO 490 J=1,L
      K=L-J+1
      A(I,K+1)=A(I,K)
```

```
      V(I,K+1)=A(I,K+1)*VHA(I,K+1)
      IF(VHA(I,K+1).EQ.ER) V(I,K+1)=ER
490   VRES=VRES+V(I,K+1)
500   A(I,1)=AREG(I)
      X=PFA100.
      VGROW=VRES-VTOT+VHARV+VFLOSS-VSALV
```

The gross annual growth, VGROW, is equal to the net change in the inventory of the forest, VRES - VTOT, plus the volume of standing trees in the harvest, VHARV - VSALV, plus the volume of trees that are lost to fire during the year. VSALV is the volume of wood that was burnt in earlier years and which is part of the current year's harvest.

```
      VTOT=VRES
      VCUT=VHARV
      VHARV=VHARV-VSALV
      IOUT(1)=AFIR+.5
      IOUT(2)=VRES+.5
      IOUT(3)=VHARV+.5
      IOUT(4)=VSALV+.5
      IOUT(5)=VCUT+.5
      IOUT(6)=VFLOSS+.5
      IOUT(7)=VFSALV+.5
      IOUT(8)=VGROW+.5
      IOUT(9)=ASUM+.5
      IOUT(10)=SALVA+.5
      IOUT(11)=AHARV+.5
      AV(1)=AV(1)+X
      AV(2)=AV(2)+AFIR
      AV(3)=AV(3)+VRES
      AV(4)=AV(4)+VHARV
      AV(5)=AV(5)+VSALV
      AV(6)=AV(6)+VCUT
      AV(7)=AV(7)+VFLOSS
      AV(8)=AV(8)+VFSALV
      AV(9)=AV(9)+VGROW
      AV(10)=AV(10)+ASUM
      AV(11)=AV(11)+SALVA
      AV(12)=AV(12)+AHARV
      IF(YNK.EQ.YES) WRITE(2,510) N,X,(IOUT(I),I=1,11)
510   FORMAT(I5,F7.2,10I10)
      IF(YSAS.EQ.YES) WRITE(10,515) N,(IOUT(I),I=1,11),DATE,
     1(TEST(I),I=1,ITEST)
515   FORMAT(I4,I6,10I10,E9.4,1X,8A1)
      DO 520 I=1,7
520   JOUT(I)=JOUT(I)+IOUT(I)
      JOUT(2)=VRES+.5
      DO 525 I=9,11
```

```
525   JOUT(1)=JOUT(I)+IOUT(I)
      IF(N/KINT*KINT.NE.N) GO TO 570
      K=N-KINT+1
      NPER=NPER+1
      IF(LINES.LT.45) GO TO 540
      WRITE(3,530) (TEST(I),I=1,ITEST),DATE
530   FORMAT(1H1,115X,'Test: ',<ITEST>A1/116X,'Date:',F8.4//
     11X,'Period Years',17X,'A r e a',27X,'M e r c h a n t a b l e  v o
     2 l u m e  ( m * * 3)'/3X,'No.'/
     317X,'Burnt    Harvested Salvaged Total cut   Residual  Harvested
     4 Salvaged  Total cut         Fire loss       Growth'/
     515X,'(%)   (ha)    (ha)     (ha)      (ha)',51X,'Total  Salvageabl
     6e'//)
      LINES=10
540   Y=JOUT(1)
      Y=Y/ATUT*100.
      JOUT(8)=JOUT(2)-JVOL+JOUT(3)+JOUT(6)-JOUT(4)
      JVOL=JOUT(2)
      WRITE(3,550) NPER,K,Y,JOUT(1),(JOUT(I),I=9,11),(JOUT(I),I=2,8)
550   FORMAT(1X,I4,I6,'-',F7.2,I7,I8,I9,I10,I12,5I11,I10)
      DO 555 I=1,12
555   JOUT(I)=0
      LINES=LINES+1
      IF(LINES/545.NE.LINES) GO TO 570
      WRITE(3,560)
560   FORMAT(20X)
570   IF(JLINES/10*10..EQ.JLINES) WRITE(5,530) (TEST(I),I=1,ITEST),DATE
      WRITE(5,550) N,N,X,IOUT(1),(IOUT(I),I=9,11),(IOUT(I),I=2,8)
      JLINES=JLINES+1
      IF(YNT.EQ.YES.AND.N/IINT*IINT.EQ.N) CALL TABLE(IC,N,ITEST,TEST,
     1DATE,KLINES,ICLASS,A,V)
      IF(YNP.EQ.YES.AND.N/JINT*JINT.EQ.N) CALL PLOTAC(IC,N,ITEST,TEST,
     1DATE,JCLASS,A,AMAX,YSAS)
580   CONTINUE
      IF(LINES.LT.45) GO TO 582
      WRITE(3,530) (TEST(I),I=1,ITEST),DATE
      LINES=10
582   F=NYR
      AV(1)=AV(1)/F
      DO 584 I=2,12
      AV(I)=AV(I)/F
584   IOUT(I-1)=AV(I)+.5
      WRITE(3,586) AV(1),IOUT(1),(IOUT(I),I=9,11),(IOUT(I),I=2,8)
586   FORMAT(/1X,'Averages:  ',F7.2,I7,I8,I9,I10,I12,5I11,I10)
      WRITE(5,590)
590   FORMAT(///' Input data for this test are listed in file FORMOD.INP
     1.  Output for the'//'  test is listed in file FORMOD.OUT, that als
     2o contains instructions for'//'  obtaining the optional outputs'//
     3)
```

```
      WRITE(3,220) (TEST(I),I=1,ITEST),TITLE
      IF(YNY.EQ.YES) WRITE(3,600)
600   FORMAT(//10X,'Data for plotting yield curves are stored on file F
     1IELD.PLT (Format: F4.0,F8.2)')
      IF(YNF.EQ.YES) WRITE(3,610)
610   FORMAT(//10X,'Data for plotting fire probability curves are store
     1 on file FPFIRE.PLT (Format: F4.0,F8.4)')
      IF(YNT.EQ.YES) WRITE(3,620)
620   FORMAT(//10X,'Age-class distribution tables are stored on file AG
     1CLA.TAB')
      IF(YNT.EQ.YES) CLOSE(UNIT=1)
      IF(YNP.EQ.YES) WRITE(3,630) AMAX
630   FORMAT(//10X,'Data for plotting age-class distributions are store
     1 on file AGECLA.PLT   (Format: F4.0,F8.0)'/
     220X,'Maximum area (ha) in any class =',F8.0)
      CLOSE(UNIT=1)
      IF(YNR.NE.YES) GO TO 638
      J=-1
      X=-1.
      DO 637 I=1,11
637   IOUT(I)=-1
```

The Institute's software for plotting on the Nicolet ZETA8 Plotter requires that the last record in any data set contains values of -1 for each variable.

```
      WRITE(2,510) J,X,(IOUT(I),I=1,11)
      WRITE(3,635)
635   FORMAT(//10X,'Data for plotting results are stored on file FORRES
     1PLT   (Format: F5.0,F7.2,10F10.0)'/
     210X,'To transfer these data to a format suitable for plotting, ru
     3 program PLORES')
638   IF(YNS.NE.YES) GO TO 670
      OPEN(UNIT=1,NAME='FOREST.DAT',FORM='FORMATTED',STATUS='NEW')
      WRITE(1,146) DATE,ITEST,(TEST(I),I=1,ITEST)
      DO 640 I=1,IC
      MAGE(I)=0
      DO 640 J=1,225
      IF(A(1,J).GT.0..AND.J.GT.MAGE(I)) MAGE(I)=J
640   CONTINUE
      WRITE(1,150) IC,IV,(MAGE(I),I=1,IC)
      WRITE(1,160) ISALV,(HSALV(I),I=1,5)
      DO 650 I=1,IC
      WRITE(1,160) I,AR(I)
      DO 650 J=1,MAGE(I)
650   WRITE(1,160) J,A(I,J),V(I,J)
      CLOSE(UNIT=1)
      WRITE(3,660)
660   FORMAT(//10X,'Final state of the forest is stored on file FOREST.
```

```
     1AT.    These data may be used'/23X,'as input to another simulation
     2 run')
670   IF(YSAS.EQ.YES) WRITE(3,675)
675   FORMAT(//10X,'Data for SAS/GRAPH plotting are stored on file SGRAP
     1H.DAT')
      WRITE(3,680) ISEED
680   FORMAT(///20X,'Final value of random number seed =',I11//)
      STOP
      END
```

Subroutine VOLUME generates yield values, VHA(I,J), and growth rates, GHA(I,J), for each site class, I, and age class, J.

```
      SUBROUTINE VOLUME(IC,IV,YNY,ER,VHA,GHA)
      VIRTUAL VHA(3,225),GHA(3,225)
      BYTE YNY,YES
      DATA YES/'Y'/
      WRITE(5,10)
      WRITE(2,10)
10    FORMAT(///' Choose the yield function to be used in this test from
     1:'///'    1.  Plonski''s yield tables for black spruce'/
     2'         (merchantable  volume in m**3/ha)'/
     3'    2.  Plonski''s yield tables for red pine'/
     4'         (merchantable volume in m**3/ha)'/
     5'    3.  Reserved for future use'//
     6' ENTER your choice (1, 2 or 3):  ',$)
      READ(5,*) IV
      WRITE(2,*) IV
      DO 55 I=1,IC
      S=I
      DO 55 J=1,225
      VHA(I,J)=0.
      GHA(I,J)=0.
      A=J-1
      IF(J.EQ.1) A=ER
      GO TO (20,30,40),IV
20    G=3.38096+.787593*S-.140768E-5*A**3-.471908*S*S+.00235218*A*S*S
      F=-265.848+3.38096*A+.787593*A*S-.351920E-6*A**4+156.416*S-
     1319.415*ALOG(S)-.471908*A*S*S+.00117609*A**A*S*S
      GO TO 50
30    G=358.995/A-22.8768*S/A-2.18347+2.90039*ALOG(S)/A+.311790E-2*A*S
     1-.694506E-3*A*S*S
      F=-920.299+358.995*ALOG(A)-22.8768*S*ALOG(A)-2.18347*A+
     12.90039*ALOG(A)*ALOG(S)+.155895E-2*A*A*S-.347253E-3*A*A*S*S
```

F is the yield function (derived from Plonski's yield tables) and G is the growth function obtained by taking the first derivative of F.

```
      GO TO 50
40    F=0.
      G=0.
50    IF(J.EQ.1) GO TO 55
      IF(F.LE.0..AND.VHA(I,J-1).EQ.0.) GO TO 55
      VHA(I,J)=AMAX1(F,ER)
      GHA(I,J)=G
```

Negative values of G are legitimate but negative values of F are not. These are set equal to 0.1E-10.

```
55    CONTINUE
      WRITE(5,60)
      WRITE(2,60)
60    FORMAT(///' Do you want a data file established to plot yield'/
     1'   curves (Y/N)?  ',$)
      READ(5,70) N,YNY
70    FORMAT(Q,45A1)
      WRITE(2,75) YNY
75    FORMAT(10X,45A1)
      IF(YNY.NE.YES) RETURN
      OPEN(UNIT=1,NAME='FYIELD.PLT',FORM='FORMATTED',STATUS='NEW')
      GO TO (80,100,120),IV
80    WRITE(1,90)
90    FORMAT(' BLACK SPRUCE')
      GO TO 140
100   WRITE(1,110)
110   FORMAT(' RED PINE')
      GO TO 140
120   RETURN
140   WRITE(1,145)
145   FORMAT(' MERCHANTABLE VOLUME (MAA3/HA)'/' PLONSKI (1974)')
      DO 170 I=1,IC
      DO 160 J=1,225
      IF(VHA(I,J).LE.ER) GO TO 160
      WRITE(1,150) J,VHA(I,J)
150   FORMAT(I4,F8.2)
160   CONTINUE
      J=-1
      F=-1.
170   WRITE(1,150) J,F
      CLOSE(UNIT=1)
      WRITE(5,180)
      WRITE(2,180)
180   FORMAT(//' Data for plotting yield curves are stored on file '/
```

```
     1'   FYIELD.PLT (Format: F4.0,F8.2)')
      RETURN
      END
```

Subroutine FFIRE assigns a relative proportion, FP(I,J), of the area in each site class, I, and age class, J, that will be burnt in any year. This proportion may be fixed (IFR = 1) or dependent on I and J (IFR = 2). The actual area burnt in any any age class - site class combination in any year, will be dependent on the total area that is burnt. This may again be fixed (IAF = 1) or drawn at random from a specified Weibull distribution (IAF = 2). The function, F, is illustrated in Figure 3 and an example of a Weibull distribution is shown in Figure 2.

```
      SUBROUTINE FFIRE(IC,IV,IAF,IFR,YNF,FF,FP,WB,WC,AR)
      DIMENSION AR(3)
      VIRTUAL FP(3,225)
      BYTE YNF,YES
      DATA YES/'Y'/
      WRITE(5,10)
      WRITE(2,10)
10    FORMAT(///' The relative proportion of the area in an age class'/
     1'   that is burnt in any year may be:'//
     2'   1.  Constant'/'   2.  Dependent on age and site class'//
     3' ENTER your choice (1 or 2):  ',$)
      READ(5,*) IFR
      WRITE(2,*) IFR
      IF(IFR.NE.1) GO TO 30
      DO 20 I=1,IC
      DO 20 J=1,225
20    FP(I,J)=1.
      GO TO 60
30    DO 40 I=1,IC
      S=I
      DO 40 J=1,225
      A=J-1
      IF(J.EQ.1) A=.0001
      GO TO (34,34,36),IV
34    F=.0284+.5047E-11*A**5-.9224E-4*A*A+.0007492*ALOG(A)-.3353E-8*A**4
     1+.003540*A-.4139E-8*A**3*S+.8554E-6*A**3+.7035E-4*A*S
      F=F*.1
      GO TO 40
36    F=1.
40    FP(I,J)=F
60    WRITE(5,70)
      WRITE(2,70)
70    FORMAT(///' Do you want a data file established to plot fire/stand
```

```
     1'//'   age probability curves (Y/N)?  ',$)
      READ(5,80) N,YNF
80    FORMAT(Q,45A1)
      WRITE(2,85) YNF
85    FORMAT(10X,45A1)
      IF(YNF.NE.YES) GO TO 205
      OPEN(UNIT=1,NAME='FPFIRE.PLT',FORM='FORMATTED',STATUS='NEW')
      GO TO (90,110,130),IV
90    WRITE(1,100)
100   FORMAT(' BLACK SPRUCE')
      GO TO 150
110   WRITE(1,120)
120   FORMAT(' RED PINE')
      GO TO 150
130   WRITE(1,140)
140   FORMAT(' RESERVED FOR FUTURE USE')
150   WRITE(1,160)
160   FORMAT(' FIRE PROBABILTY'//' CURVES')
      DO 190 I=1,IC
      DO 170 J=1,225
      IF(FP(I,J).GT.1.) FP(I,J)=1.
      IF(FP(I,J).LT.0.) FP(I,J)=0.
170   WRITE(1,180) J,FP(I,J)
180   FORMAT(I4,F8.4)
      J=-1
      F=-1.
190   WRITE(1,180) J,F
      WRITE(5,200)
      WRITE(2,200)
200   FORMAT(///' Data for plotting fire probability curves are store
     1'   on file FPFIRE.PLT (Format: F4.0,F8.4)')
      CLOSE(UNIT=1)
205   WRITE(5,210)
      WRITE(2,210)
210   FORMAT(///' The proportion of the total area that is burnt in a
     1//'   year may be:'///'   1.  Constant'//
     2'   2.  Variable with a Weibull distribution'//
     3' ENTER your choice (1 or 2):  ',$)
      READ(5,*) IAF
      WRITE(2,*) IAF
      PF=0.
      WB=0.
      WC=0.
      IF(IAF.EQ.2) GO TO 230
      WRITE(5,220)
      WRITE(2,220)
220   FORMAT(//' ENTER percentage of the total area that is burnt'//
     1'   each year:  ',$)
      READ(5,*) PF
```

```
      WRITE(2,*) PF
      PF=PF*.01
      RETURN
230   WRITE(5,240)
      WRITE(2,240)
240   FORMAT(//' ENTER 'B' and 'C' parameters of the Weibull function:'/
     1/'     CDF = 1-exp[-(X/B)**C]'//
     2' where X = the proportion of the area that is burnt'//
     3' e.g. ENTER 0.001,0.4:  ',$)
      READ(5,*) WB,WC
      WRITE(2,*) WB,WC
      RETURN
      END
```

The parameters that control the different forest management options are input from the terminal by this subroutine. To aid the user, a description of the options, and of the functions of each parameter, appears on the screen at the time of input. The file SUBR.TXT (UNIT = 11) is a text file containing most of this information.

```
      SUBROUTINE MANAGE(IC,IH,MHA,MHO,MINA,AAC,HMIN,PSALV,ISALV,FSALV,
     1YNH,COMPF,IAV,ALO,AMN,AUP,VLO,VUP)
      DIMENSION MHA(3),MHO(3)
      BYTE YNH,YES,ITXT(80)
      DATA YES/'Y'/
      WRITE(2,4)
      WRITE(5,4)
4     FORMAT(/20X)
      DO 10 I=1,20
      READ(11,5) N,ITXT
5     FORMAT(Q,80A1)
      WRITE(2,7) (ITXT(J),J=1,N)
7     FORMAT(1H+,80A1)
10    WRITE(5,7) (ITXT(J),J=2,N)
      WRITE(2,4)
      WRITE(5,4)
      READ(5,*) IH
      WRITE(2,*) IH
      WRITE(2,4)
      WRITE(5,4)
      IAV=0
      IF(IH.LT.4) GO TO 18
      DO 15 I=21,39
      READ(11,5) N,ITXT
      WRITE(2,7) (ITXT(J),J=1,N)
15    WRITE(5,7) (ITXT(J),J=2,N)
      WRITE(2,4)
```

```
      WRITE(5,4)
      READ(5,*) IAV
      WRITE(2,*) IAV
      IF(IAV.EQ.2) GO TO 1504
      WRITE(2,1500)
      WRITE(5,1500)
1500  FORMAT(//' ENTER area (ha) to be harvested each year and lower and
     1'/'   upper limits (e.g. 1200,800,2000):'/)
      READ(5,*) AMN,ALO,AUP
      WRITE(2,*) AMN,ALO,AUP
      WRITE(2,1502)
      WRITE(5,1502)
1502  FORMAT(/' ENTER lower and upper limits on volume (m**3) to be'/
     1'   harvested each year (e.g. 100000,125000):'/)
      READ(5,*) VLO,VUP
      WRITE(2,*) VLO,VUP
      AAC=(VLO+VUP)*.5
      GO TO 18
1504  WRITE(2,1506)
      WRITE(5,1506)
1506  FORMAT(//' ENTER volume (m**3) to be harvested each year and lower
     1'/'   and upper limits (e.g. 120000,100000,125000):'/)
      READ(5,*) AAC,VLO,VUP
      WRITE(2,*) AAC,VLO,VUP
      WRITE(2,1508)
      WRITE(5,1508)
1508  FORMAT(/' ENTER lower and upper limits on area (ha) to be harveste
     1d'/'   each year (e.g. 800,2000):'/)
      READ(5,*) ALO,AUP
      WRITE(2,*) ALO,AUP
      AMN=(ALO+AUP)*.5
18    WRITE(5,20)
      WRITE(2,20)
20    FORMAT(//' Do you want the salvaging option (Y/N)?  ',$)
      READ(5,30) N,YNH
30    FORMAT(Q,45A1)
      WRITE(2,40) YNH
40    FORMAT(10X,<N>A1/)
      WRITE(5,4)
      IF(IH.GT.3) GO TO 44
      DO 42 I=21,39
42    READ(11,5) N,ITXT
44    DO 45 I=40,59
      READ(11,5) N,ITXT
      WRITE(2,7) (ITXT(J),J=1,N)
45    WRITE(5,7) (ITXT(J),J=2,N)
      WRITE(2,4)
      WRITE(5,4)
      READ(5,*) COMPF
```

```
      IF(COMPF.LE.0.) COMPF=100.
      WRITE(2,*) COMPF
      COMPF=COMPF*.01
      GO TO (160,50,50,120,120),IH
50    WRITE(5,60)
      WRITE(2,60)
60    FORMAT(//' For each site class, ENTER age at which "overmature"'/
     1'   stands will be harvested:  ')
      DO 80 I=1,IC
      WRITE(5,70) I
70    FORMAT('   Site class',I3,':  ',$)
      READ(5,*) MHA(I)
      IF(MHA(I).GT.225) MHA(I)=225
80    WRITE(2,90) I,MHA(I)
90    FORMAT('   Site class',I3,I5)
      IF(IH.NE.3) GO TO 160
      WRITE(5,100)
      WRITE(2,100)
100   FORMAT(//' For each site class, ENTER rotation age:')
      DO 110 I=1,IC
      WRITE(5,70) I
      READ(5,*) MHO(I)
110   WRITE(2,90) I,MHO(I)
      GO TO 160
120   WRITE(5,140)
      WRITE(2,140)
140   FORMAT(//' ENTER minimum volume for harvesting (m**3/ha):  ',$)
      READ(5,*) HMIN
      WRITE(2,*) HMIN
      WRITE(5,150)
      WRITE(2,150)
150   FORMAT(//' ENTER minimum age for harvesting:  ',$)
      READ(5,*) MINA
      WRITE(2,*) MINA
160   IF(YNH.NE.YES) RETURN
      WRITE(5,170)
      WRITE(2,170)
170   FORMAT(//' ENTER percentage of fire-destroyed wood that can be'/
     1'   salvaged:  ',$)
      READ(5,*) PSALV
      WRITE(2,*) PSALV
      PSALV=PSALV*.01
      WRITE(5,180)
      WRITE(2,180)
180   FORMAT(//' ENTER salvage period (< 5 years):  ',$)
      READ(5,*) ISALV
      WRITE(2,*) ISALV
      IF(ISALV.GT.4) ISALV=4
      GO TO (250,190,210,230),ISALV
```

```
190   WRITE(5,200)
      WRITE(2,200)
200   FORMAT(//' (two-thirds salvaged in year 1, one-third in year 2)
      GO TO 250
210   WRITE(5,220)
      WRITE(2,220)
220   FORMAT(//' (half salvaged in year 1, one-third in year 2,'/
     1'   one-sixth in year 3)')
      GO TO 250
230   WRITE(5,240)
      WRITE(2,240)
240   FORMAT(//' (half salvaged in year 1, one-quarter in year 2,'/
     1'   one-eighth in each of years 3 and 4)')
250   WRITE(5,260)
      WRITE(2,260)
260   FORMAT(//' ENTER percentage of the area burnt in any year, abov
     1'   which salvaging operations will take place: ',$)
      READ(5,*) FSALV
      WRITE(2,*) FSALV
      FSALV=FSALV*.01
      RETURN
      END
```

Subroutine TABLE, on request (YNT = 'Y'), produces the age class distribution tables at intervals (IINT) that are specified by the user. The number of years (ICLASS) in each age class has also to be specified. The output is stored on file AGECLA.TAB that can be listed directly on a printer.

```
      SUBROUTINE TABLE(IC,IYR,ITEST,TEST,DATE,LINES,ICLASS,A,V)
      DIMENSION A(3,225),IND(3),SA(3),SV(3)
      VIRTUAL V(3,225)
      INTEGER*4 IA(3),IV(3)
      BYTE TEST(8)
      JL=0
      MAX=0
      DO 10 I=1,IC
      DO 10 J=1,225
      IF(A(I,J).GT.0..AND.J.GT.MAX) MAX=J
10    CONTINUE
      IF(LINES.LT.54) GO TO 60
      DO 30 I=1,IC
30    IND(I)=I
      WRITE(4,40) (TEST(I),I=1,ITEST),DATE,(IND(I),I=1,IC)
40    FORMAT(1H1,110X,'Test No.: ',<ITEST>A1/111X,'Date:',F8.4//
```

```
     110X,'Site class:',I14,4I17)
      WRITE(4,50)
50    FORMAT(/10X,'Year  Age  Range',<IC>('  Area   Volume  ')/
     115X,'class      ',<IC>('  (ha)  (m**3/ha)')/)
      LINES=7
60    DO 95 I=1,MAX,ICLASS
      M=I+ICLASS-1
      DO 70 J=1,IC
      SA(J)=0.
      SV(J)=0.
      DO 70 K=I,M
      SA(J)=SA(J)+A(J,K)
70    SV(J)=SV(J)+V(J,K)
      DO 75 J=1,IC
      IA(J)=SA(J)+.5
75    IV(J)=SV(J)+.5
      IF(JL/10*10.NE.JL) GO TO 85
      WRITE(4,80)
80    FORMAT(20X)
      LINES=LINES+1
85    IF(LINES.LT.54) GO TO 90
      WRITE(4,40) (TEST(L),L=1,ITEST),DATE,(IND(L),L=1,IC)
      WRITE(4,50)
      LINES=7
90    JL=JL+1
      WRITE(4,100) IYR,JL,I,(IA(J),IV(J),J=1,IC)
100   FORMAT(10X,I4,2I5,'-',5(I8,I9))
95    LINES=LINES+1
      RETURN
      END
```

Subroutine PLOTAC, on request (YNP = 'Y'), produces an output file (AGECLA.PLT) that can be used by Institute library programs to produce histograms of the age-class distributions on the ZETA8 plotter. The number of years in each age class (JCLASS) and the interval between successive plots (JINT) need not be the same as for the tabular output.

```
      SUBROUTINE PLOTAC(IC,IYR,ITEST,TEST,DATE,JCLASS,A,AMAX,YSAS)
      DIMENSION A(3,225)
      BYTE TEST(8),YSAS,YES
      DATA YES/'Y'/
      WRITE(1,10) (TEST(I),I=1,ITEST),DATE,IYR
10    FORMAT(' AGE-CLASS DISTRIBUTION'/' TEST: ',<ITEST>A1,3X,'DATE:',
     1F8.4/' YEAR:',I4)
      MAX=0
      DO 15 I=1,IC
```

```
      DO 15 J=1,225
      IF(A(I,J).GT.0..AND.J.GT.MAX) MAX=J
15    CONTINUE
      DO 50 I=1,IC
      DO 30 J=1,MAX,JCLASS
      SA=0.
      M=J+JCLASS-1
      DO 20 K=J,M
20    SA=SA+A(I,K)
      IF(SA.GT.AMAX) AMAX=SA
      K=J-1
      IF(YSAS.EQ.YES) WRITE(12,25) IYR,I,K,SA,DATE,(TEST(L),L=1,ITEST)
25    FORMAT(3I5,F10.1,F10.4,1X,<ITEST>A1)
30    WRITE(1,40) K,SA,M,SA
40    FORMAT(I4,F8.0)
      SA=0.
      WRITE(1,40) M,SA
      K=-1
      SA=-1.
50    WRITE(1,40) K,SA
      RETURN
      END
```

This is probably the most complex part of the program for FIREFOR. Subroutine HARV determines the age class - site class combinations in which harvesting will take place according to the different management and salvaging options.

```
      SUBROUTINE HARV(IC,IH,MHA,MHO,ER,AAC,VHARV,HSALV,A,V,P,AREG,
     1VHA,GHA,VSALV,YNH,COMPF,MINA,HMIN,ASUM,ASALV,SALVA,AHARV,
     2IAV,ALO,AMN,AUP,VLO,VUP)
      DIMENSION MHA(3),MHO(3),AREG(3),HSALV(5),A(3,225),ASALV(5)
      VIRTUAL P(3,225),V(3,225),VHA(3,225),GHA(3,225)
      BYTE YNH,YES
      DATA YES/'Y'/
10    DO 20 I=1,IC
      DO 20 J=1,225
      IF(VHA(I,J).GT.0..AND.VHA(I,J).LE.ER) P(I,J)=1.
```

This statement ensures that any age class in which all the trees have died is included in the harvested area during the current year and that it will be regenerated.

```
20    CONTINUE
      GO TO (90,30,30,60,60),IH
30    DO 50 I=1,IC
```

```
      K=MHA(I)
      DO 40 J=K,225
      P(I,J)=COMPF
      IF(A(I,J).LE.1.) P(I,J)=1.
40    CONTINUE
      IF(IH.EQ.2) GO TO 50
      P(I,MHO(I))=COMPF
      IF(A(I,MHO(I)).LE.1.) P(I,MHO(I))=1.
50    CONTINUE
      GO TO 90
```

The above section ensures that all stands greater than a specified age, MHA(I), for each site class, are harvested (options 2 and 3). For option 3, stands that have reached the rotation age, MHO(I), are also harvested.

```
60    ZV=0.
      ZA=0.
      IF(YNH.NE.YES) GO TO 70
      ZV=HSALV(1)
      ZA=ASALV(1)
C***  ZA and ZV are the area and volume that have been cut so far
70    IF(IAV.EQ.1.AND.ZA.GE.AMN.AND.ZV.LE.VUP.AND.ZV.GE.VLO.OR.
     1IAV.EQ.2.AND.ZV.GE.AAC.AND.ZA.LE.AUP.AND.ZA.GE.ALO) GO TO 90
```

For management options 4 and 5, this complex and lengthy IF statement checks to see if all the specifications for the prescribed annual cut have been met; if they have, then harvest allocation is completed. If harvest regulation is by area (IAV = 1), it checks to see if the area alocated so far, ZA, is greater than the minimum area, ALO. If it is, and the allocated volume, ZV, is within the allowable range (VLO -VUP), then sufficient area has been allocated. Similarly, if harvest regulation is by volume (IAV = 2), a check is made to see if ZV is greater than the minimum volume, VLO, and within the permissible area range (ALO - AUP). If not all of these conditions are satisfied, harvest allocation continues with the call to subroutine MAXVOL that selects the next site class - age class combination (II,JJ) for harvesting.

```
      CALL MAXVOL(IC,IH,MINA,II,JJ,HMIN,VHA,GHA,V,ER)
      IF(II.EQ.0) GO TO 90
      VIJ=V(II,JJ)
      AIJ=A(II,JJ)
      VC=VIJ
      AR=AIJ
      IF(AR.LE.1.) GO TO 75
      VC=VC*COMPF
      AR=AR*COMPF
```

```
75      IF(IAV.EQ.1) PC=AMAX1((ALO-ZA)/AIJ,AMIN1((AMN-ZA)/AIJ,
     1(VUP-ZV)/VIJ),AMIN1((AUP-ZA)/AIJ,(VLO-ZV)/VIJ))
        IF(IAV.EQ.2) PC=AMAX1((VLO-ZV)/VIJ,AMIN1((AAC-ZV)/VIJ,
     1(AUP-ZA)/AIJ),AMIN1((VUP-ZV)/VIJ,(ALO-ZA)/AIJ))
```

The above IF statements calculate the proportion, PC, of combination (II,JJ) that must be harvested. For area control (IAV = 1), if ZA is less than the minimum allowable area (ALO), the proportion: (ALO-ZA)/AIJ would ensure that the area harvested is brought up to the minimum. If ZA is greater than ALO, but less than the prescribed area to be harvested (AMN), the proportion: (AMN-ZA)/AIJ would ensure that the area is brought up to that level. However, if this would cause the volume (ZV) to exceed the upper volume limit (VUP), the proportion would be restricted to (VUP-ZV)/VIJ. If ZV is less than the lower volume limit (VLO), the proportion: (VLO-ZV)/VIJ would ensure that the volume harvested is brought up to the minimum. However, if this would cause the upper area limit (AUP) to be exceeded, the proportion to be harvested would be restricted to (AUP-ZA)/AIJ.

Similar logic is used to determine the value of PC under volume control (IAV = 2).

However the value of PC is calculated, it should always be greater than 0 but it may not necessarily be less than 1. The next two statements ensure that PC falls within that range.

```
      IF(PC.LT.0.) PC=0.
      IF(PC.GT.1.) PC=1.
      P(II,JJ)=PC
      IF(PC.LT.COMPF) GO TO 90
      P(II,JJ)=COMPF
      IF(AIJ.LE.1.) P(II,JJ)=1.
      ZV=ZV+VC
      ZA=ZA+AR
      V(II,JJ)=-VIJ
```

Areas of less than 1 ha are always harvested in total. The volume of class (II,JJ) is made negative so that it is not considered as a candidate for harvesting in subsequent calls to subroutine MAXVOL.

```
      GO TO 70
CAAA  Calculate actual harvest
```

At this stage, every combination of site class and age class will be assigned a proportion, P(I,J), for harvesting. The majority will have a value of 0, a few will have a value between 0 and COMPF (the compliance factor), and the rest will have a

value of COMPF. The next section calculates the areas and volumes to be harvested from this information.

```
90    VSALV=0.
      SALVA=0.
      IF(YNH.NE.YES) GO TO 120
      VSALV=HSALV(1)
      SALVA=ASALV(1)
      DO 100 I=1,4
      ASALV(I)=ASALV(I+1)
100   HSALV(I)=HSALV(I+1)
      ASALV(5)=0.
      HSALV(5)=0.
120   VHARV=VSALV
      AHARV=SALVA
      DO 130 I=1,IC
      AREG(I)=0.
      DO 130 J=1,225
      V(I,J)=ABS(V(I,J))
      IF(P(I,J).LE.0.) GO TO 130
      IF(V(I,J).LE.0.) GO TO 125
      H=P(I,J)*V(I,J)
      V(I,J)=V(I,J)-H
      VHARV=VHARV+H
125   H=A(I,J)*P(I,J)
      ASUM=ASUM+H
      AREG(I)=AREG(I)+H
      AHARV=AHARV+H
      A(I,J)=A(I,J)-H
130   CONTINUE
      RETURN
      END
```

Subroutine MAXVOL identifies the next site class - age class combination (II,JJ) to be scheduled for harvesting. For option 4, this will be the combination with the highest volume/ha among those not already tagged [V(I,J) < 0] for harvesting. For option 5, the criterion for selection is the lowest growth/ha.

```
      SUBROUTINE MAXVOL(IC,IH,MINA,II,JJ,HMIN,VHA,GHA,V,ER)
      VIRTUAL VHA(3,225),GHA(3,225),V(3,225)
      II=0
      JJ=0
      VMAX=0.
      GMIN=99999.
      L=JMAX0(1,MINA)
```

```
      DO 20 I=1,IC
      DO 20 J=L,225
      IF(V(I,J).LE.EK.OR.VHA(I,J).LT.HMIN) GO TO 20
      IF(IH.EQ.5) GO TO 10
      IF(VHA(I,J).LE.VMAX) GO TO 20
      VMAX=VHA(I,J)
      II=I
      JJ=J
      GO TO 20
10    IF(GHA(I,J).GT.GMIN) GO TO 20
      GMIN=GHA(I,J)
      II=I
      JJ=J
20    CONTINUE
      RETURN
      END
```

The knowledgeable FORTRAN programmer will recognize that this program is not the most efficient: changes could undoubtedly be made to reduce the amount of code and to speed up certain sections. However, the program evolved over a period of several months during which time, as often happens in program development, a number of additions, deletions and other modifications were made. The program has been extensively, but by no means exhaustively, tested and appears to be working satisfactorily. There is therefore a reluctance to make any non-essential or cosmetic changes.

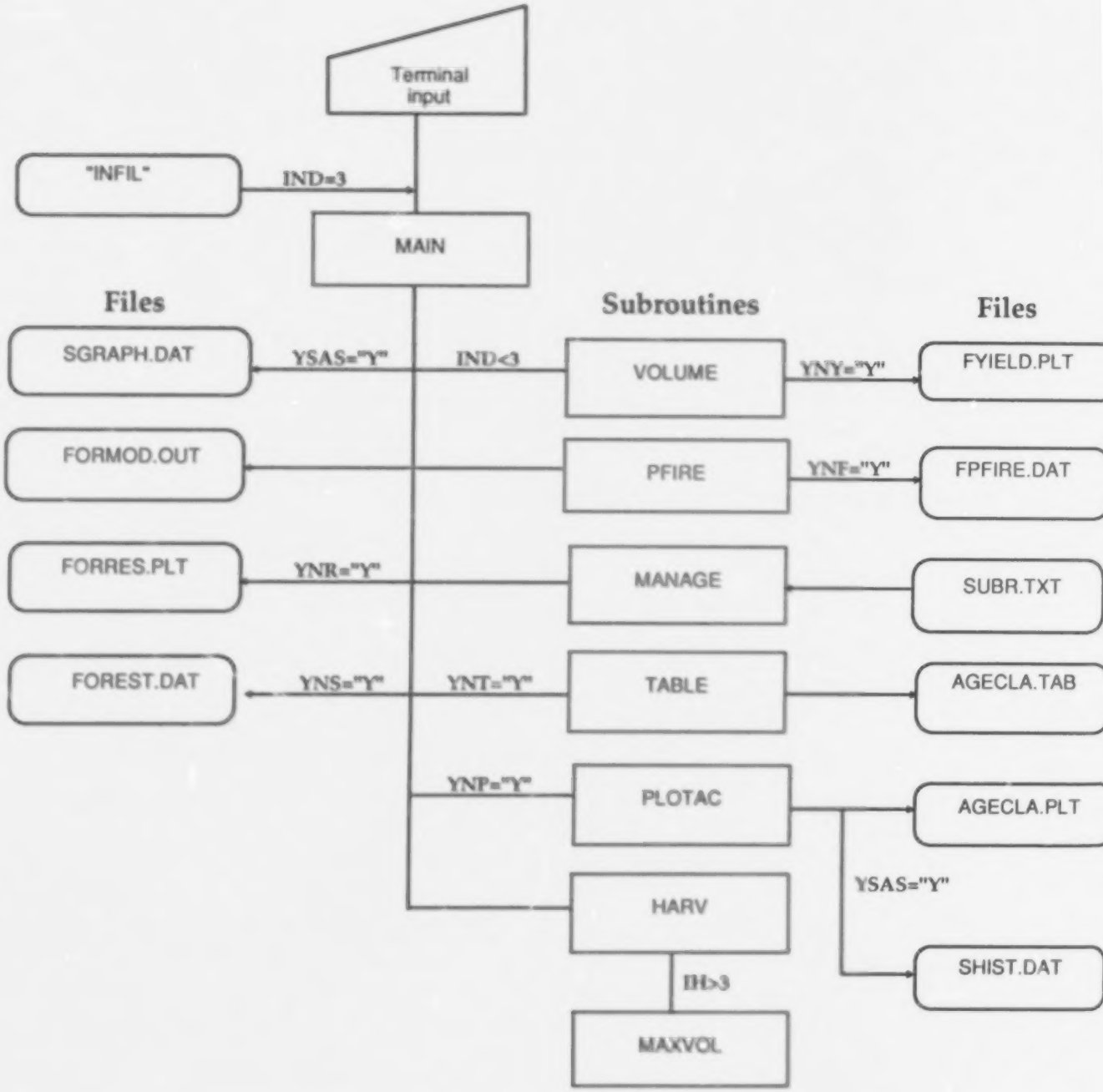
As a further aid to the user, the major variables used in the program are listed and described in Appendix II.

Table I-1. FIREOR input and output files.

File name	Unit No.	I/O[1]	Condition	Description
AGECLA.PLT	1	O	YNP='Y'	Data for plotting age-class distribution histograms using PNFI plotting procedures.
AGECLA.TAB	4	O	YNT='Y'	Lists the age-class distribution tables.
FOREST.DAT	1	O	YNS='Y'	Data for final state of the forest (to be used as input to another test - see 'INFIL').
FORMOD.INP	2	O		Lists the terminal input.
FORMOD.OUT	3	O		Lists the results at the end of each period (area burnt, residual volume, growth, etc.).
FORRES.PLT	2	O	YNR='Y'	Data for plotting results using PNFI plotting procedures.
FPFIRE.PLT	1	O	YNF='Y'	Data for plotting the relative proportion of the area burnt and age using PNFI plotting procedures.
FYIELD.PLT	1	O	YNY='Y'	Data for plotting yield curves using PNFI plotting procedures.
'INFIL'	9	I	IND=3	Data for initial forest ('INFIL' is usually FOREST.DAT generated by a previous test).
SGRAPH.DAT	10	O	YSAS='Y'	Data for plotting results using SAS/GRAPH plotting procedures.
SHIST.DAT	12	O	YSAS='Y' and YNP='Y'	Data for plotting age-class distribution histograms using SAS/GRAPH plotting procedures.
SUBR.TXT	11	I		A text file used for displaying information on the terminal screen at the time of data input.

[1] Input (I) or output (O).

SUMMARY FLOW-CHART FOR FIRFOR PROGRAM



TEST 1

Listing of Output Files:

FORMOD.OUT and AGECLA.TAB.

1-5V. TEST 1: OPTION 5-V - AAC = 125000 MAA3/YR

Forest Type: BLACK SPRUCE

I N I T I A L F O R E S T

Site class	Area (ha)	Merchantable volume (mAA3)
1	25000	2013331
2	50000	1327534
3	25000	459673
TOTAL	100000	3800538

Random number seeds:

Initial: 886332245
At start of simulation run: 886332245

Annual harvest is controlled by VOLUME.

Scheduled annual harvest (mAA3)	=	125000
Range (mAA3)	=	120000 - 130000
Area range (ha)	=	600 - 1000

The scheduled volume will be harvested each year, provided that the harvested area falls within the specified range. If necessary, the volume will be adjusted until the area falls within its range

Test: 1-5V
Date: 86.1202

Period No.	Years	Area					Merchantable volume (m^3)						
		Burnt		Harvested	Salvaged	Total cut	Residual	Harvested	Salvaged	Total cut	Fire loss		Growth
		(%)	(ha)	(ha)	(ha)	(ha)					Total	Salvageable	
1	1-	0.13	132	4253	0	4253	3886062	625000	0	625000	4056	0	714581
2	6-	0.29	286	4259	0	4259	3958906	620000	0	620000	8914	0	701758
3	11-	0.96	957	4824	0	4824	3993577	620000	0	620000	30077	0	684748
4	16-	1.62	1621	4203	274	4476	4028307	611419	8581	620000	51017	8581	688585
5	21-	1.17	1172	4029	0	4029	4079328	625000	0	625000	36985	0	713006
6	26-	0.77	771	4151	0	4151	4163797	623712	0	623712	24864	0	733045
7	31-	0.79	790	4113	0	4113	4260688	624715	0	624715	25676	0	747282
8	36-	0.41	411	3423	0	3423	4361823	630000	0	630000	13740	0	744875
9	41-	0.23	228	3826	0	3826	4491483	625000	0	625000	7809	0	762469
10	46-	3.42	3420	3846	602	4449	4509363	604024	20976	625000	119241	20977	720169
11	51-	0.08	83	3948	0	3948	4621358	620000	0	620000	2920	0	734915
12	56-	5.85	5847	3489	726	4215	4528833	598823	26177	625000	210804	52353	690925
13	61-	27.32	27324	2371	3816	6186	3723772	483738	137160	620898	979260	244746	520777
14	66-	0.82	817	2846	3739	6586	3781735	481239	133761	615000	26810	0	432251
15	71-	0.98	978	4111	0	4111	3675677	625000	0	625000	28267	0	547209
16	76-	2.44	2438	3673	432	4105	3525043	608380	11620	620000	65800	13945	511926
17	81-	5.69	5686	3286	1420	4706	3290767	578342	36658	615000	145831	34334	453239
18	86-	2.88	2879	3395	552	3947	3094093	612311	12689	625000	66175	15227	469123
19	91-	5.61	5609	3448	1266	4715	2889516	587639	27361	615000	120486	29788	476187
20	96-	0.33	326	3386	231	3617	2798836	630035	4965	635000	6745	0	541135
21	101-	0.14	135	4780	0	4780	2711974	615995	0	615995	2771	0	531904
22	106-	4.18	4176	3538	403	3941	2511366	611955	8045	620000	83325	16089	486627
23	111-	2.19	2191	3844	403	4248	2351960	611955	8045	620000	42128	0	486632
24	116-	0.25	252	4542	0	4542	2278416	625000	0	625000	4708	0	556164
25	121-	0.92	922	4600	0	4600	2263060	620000	0	620000	17639	0	622883
26	126-	0.58	584	4157	0	4157	2378885	498772	0	498772	11351	0	625348
27	131-	0.56	556	2822	0	2822	2670721	360844	0	360844	11962	0	664642
28	136-	0.05	49	2837	0	2837	3027117	387946	0	387946	1172	0	745514
29	141-	0.54	541	4727	0	4727	3146758	617988	0	617988	13929	0	751558
30	146-	0.37	374	5709	0	5709	3293157	605000	0	605000	9827	0	761226
31	151-	0.22	221	5011	0	5011	3435260	610000	0	610000	6162	0	758365
32	156-	0.24	243	4525	0	4525	3563395	620265	0	620265	7116	0	755516
33	161-	0.73	728	5321	0	5321	3679363	607562	0	607562	21835	0	745365
34	166-	0.38	380	5051	0	5051	3823185	610000	0	610000	11649	0	765471
35	171-	1.86	1856	4665	312	4977	3941190	605154	9846	615000	58941	9846	772254

Test: 1-5V
Date: 86.1202

Period No.	Years	Area					Merchantable volume (m***3)						
		Burnt (%)	Burnt (ha)	Harvested (ha)	Salvaged (ha)	Total cut (ha)	Residual	Harvested	Salvaged	Total cut	Fire loss Total	Fire loss Salvageable	Growth
36	176-	4.72	4719	4700	1172	5872	3988027	566571	38429	605000	154812	38429	729791
37	181-	0.36	362	4183	0	4183	4098971	623681	0	623681	12087	0	746712
38	186-	1.64	1640	3710	262	3973	4149447	616269	8731	625000	54695	8731	712709
39	191-	0.57	566	4856	0	4856	4187427	620000	0	620000	18875	0	676855
40	196-	0.05	52	4084	0	4084	4226888	625000	0	625000	1697	0	666158
41	201-	4.27	4269	4233	474	4707	4168760	599678	15322	615000	138341	30645	664269
42	206-	1.27	1266	3459	756	4213	4229387	600626	24374	625000	40744	9052	677623
43	211-	6.38	6383	4316	1292	5607	4118945	571909	41720	613629	206185	50065	625932
44	216-	16.42	16415	3392	2466	5860	3692083	536744	78256	615000	519291	129299	550917
45	221-	0.17	167	3411	1878	5289	3704520	555612	59388	615000	4957	0	513618
46	226-	1.81	1809	3328	363	3691	3588795	614893	10107	625000	50404	12128	539465
47	231-	0.79	790	3540	73	3612	3494059	622979	2021	625000	20516	0	546738
48	236-	4.26	4261	3438	611	4049	3319027	611757	15280	627037	106610	25242	528055
49	241-	0.74	735	3086	398	3486	3223737	620039	9961	630000	17622	0	532410
50	246-	0.49	485	3626	0	3626	3185494	625000	0	625000	11373	0	598130
51	251-	4.29	4289	3909	1066	4977	3095517	589946	25054	615000	100782	25054	575697
52	256-	0.81	812	3709	0	3709	3047095	625000	0	625000	19035	0	595613
53	261-	7.06	7064	3735	1628	5363	2834153	571842	38158	610000	165536	40292	536278
54	266-	3.80	3795	3898	91	3989	2755266	622866	2134	625000	86480	17948	578325
55	271-	0.72	721	3965	788	4753	2767699	602052	17948	620000	16290	0	612827
56	276-	1.79	1793	4141	283	4424	2775517	613495	6505	620000	41360	6505	656168
57	281-	1.79	1788	5382	135	5517	2782830	596827	3173	600000	41899	6345	642866
58	286-	1.16	1160	5126	135	5261	2781106	601827	3173	605000	27093	6640	624023
59	291-	1.25	1254	4321	284	4606	2791522	613360	6640	620000	29091	6906	646227
60	296-	1.51	1512	5243	298	5541	2767437	608094	6906	615000	34569	6576	611672
Averages:		0.48	477	806	95	901	3486832	118996	2864	121860	14000	2886	129553

1-5V. TEST 1: OPTION 5-V - AAC = 125000 MA3/YR

Age-class distribution tables are stored on file AGECLA.TAB

Final value of random number seed = -408225207

Test No.: 1-5V
Date: 86.1202

Site class:			1		2		3	
Year	Age class	Range	Area (ha)	Volume (m**3/ha)	Area (ha)	Volume (m**3/ha)	Area (ha)	Volume (m**3/ha)
0	1	1-	6043	0	11875	0	8266	0
0	2	26-	6066	171421	15267	0	4455	0
0	3	51-	8014	914849	13559	411382	4629	1081
0	4	76-	4877	927062	9300	916152	5475	275647
0	5	101-	0	0	0	0	2174	182945
25	1	1-	6538	0	11410	0	7269	0
25	2	26-	5747	177411	11277	0	7842	0
25	3	51-	5796	669839	14536	265958	4235	1555
25	4	76-	6920	1328482	12778	1379238	4454	158219
25	5	101-	0	0	0	0	1200	98624
50	1	1-	6639	0	13224	0	4428	0
50	2	26-	6109	169297	10641	0	6765	0
50	3	51-	5404	647754	10576	334154	7320	3948
50	4	76-	5540	1094638	13824	1330694	4017	141011
50	5	101-	1308	315255	1735	262591	2471	210021
75	1	1-	11970	0	23536	0	11857	0
75	2	26-	4001	106255	7859	0	2648	0
75	3	51-	3809	447437	6477	180969	4031	5075
75	4	76-	3903	788208	7457	818635	4958	185302
75	5	101-	1316	316256	4671	708018	1506	119521
100	1	1-	8315	0	17374	0	6692	0
100	2	26-	9783	283846	19272	0	9626	0
100	3	51-	3285	379362	6407	180270	2135	1837
100	4	76-	3297	657298	5551	590926	3424	146874
100	5	101-	320	76777	1397	208743	3123	272903
125	1	1-	7500	0	13950	0	6853	0
125	2	26-	7633	236613	15912	0	6110	0
125	3	51-	9011	1076005	17666	418335	8803	4154
125	4	76-	856	146566	2473	206818	1989	70250
125	5	101-	0	0	0	0	1245	104917
150	1	1-	8041	0	11625	0	2548	0
150	2	26-	7334	185353	13628	0	6687	0
150	3	51-	7461	893224	15539	479029	5962	4269
150	4	76-	2164	410289	9208	865059	8635	363259
150	5	101-	0	0	0	0	1168	92674
175	1	1-	5349	0	15475	0	6664	0
175	2	26-	7707	235617	11147	0	2436	0
175	3	51-	7059	801409	13098	354993	6425	16438
175	4	76-	4885	926819	10280	1007434	5783	264350

Test No.: 1-5V
Date: 86.1202

Site class:			1		2		3	
Year	Age class	Range	Area (ha)	Volume (m**3/ha)	Area (ha)	Volume (m**3/ha)	Area (ha)	Volume (m**3/ha)
175	5	101-	0	0	0	0	3692	334130
200	1	1-	6454	0	13372	0	8711	0
200	2	26-	4954	119612	14224	0	6220	0
200	3	51-	7033	850636	10129	208818	2212	4704
200	4	76-	6559	1284552	12152	1285160	5954	292007
200	5	101-	0	0	123	17748	1904	163651
225	1	1-	10155	0	20490	0	11977	0
225	2	26-	4447	169803	9144	0	5874	0
225	3	51-	3514	399244	10042	345407	4229	936
225	4	76-	5542	1122436	7730	761499	1696	85286
225	5	101-	1342	322934	2594	397182	1225	99793
250	1	1-	8392	0	11619	0	4449	0
250	2	26-	9256	228157	18655	0	10876	0
250	3	51-	4069	514667	8325	269192	5337	21260
250	4	76-	3283	643422	9366	1054983	3901	118296
250	5	101-	0	0	2035	298645	437	36873
275	1	1-	8188	0	20112	0	5672	0
275	2	26-	6944	198271	9597	0	3634	0
275	3	51-	7660	880542	15302	353330	8859	6815
275	4	76-	2208	427752	4989	492336	4592	232590
275	5	101-	0	0	0	0	2243	176064
300	1	1-	8445	0	15497	0	6859	0
300	2	26-	7524	197977	18421	0	5189	0
300	3	51-	6395	756513	8808	258767	3327	3860
300	4	76-	2636	473924	7274	635101	8261	325189
300	5	101-	0	0	0	0	1364	116107

APPENDIX II

List of Variables Used in the FORTRAN Program for FIREOR.

The following list describes the functions of the major variables in the FORTRAN program (Appendix I). The subscripts I and J, where given, always denote the site class and the one-year age class respectively. The program segment (either the MAIN program or one of the subroutines) indicates where each variable is read or where it is first given a value. Where appropriate, the values or the range of values that the variable may have are given. The description of each variable that is given applies to all program segments unless otherwise noted. All areas are in ha and all volumes are of merchantable wood in m^3.

Variable	Program segment	Values	Description
A(I,J)	MAIN		Area of age class J in site class I [In subroutines VOLUME and FIRE, the undimensioned variable, A, is the age in years].
AAC	MANAGE		The prescribed annual harvest (IH>3; IAF=2).
AFIR	MAIN		Annual area burnt.
AHARV	MAIN		Total area harvested each year.
AIJ	HARV		= A(II,JJ): the area of the next site class - age class combination selected for harvesting (IH>3).
ALO	MANAGE		The prescribed lower limit for the area to be harvested in any year (IH>3).
AMAX	PLOTAC		The maximum area in any site class - age class combination among all histogram plots (YNP='Y').
AMN	MANAGE		The prescribed area to be harvested in any year (IH>3; IAF=1).

Variable	Program segment	Values	Description
AR	HARV		A(I,J) adjusted for the compliance factor, COMPF (IH>3).
AR(I)	MAIN		Area of site class I.
AREG(I)	MAIN		The area of site class I that is to be regenerated.
ASUM	MAIN		Area of standing trees that is harvested.
ATOT	MAIN		Total area of the forest.
AUP	MANAGE		The prescribed upper limit for the area to be harvested in any year (IH>3).
AV(K)	MAIN		The sums of the K output variables listed in the file FORMOD.OUT. At the end of the simulation, the AV(K) are divided by the number of years to give the corresponding averages.
COMPF	MANAGE		Compliance factor: the degree of compliance with the prescribed harvesting options.
DATE	MAIN		The date in metric format: (YY.MMDD).
ER	MAIN	0.1E-10	A small number that is used sometimes instead of 0 to indicate 'presence' of a variable (where 0 indicates 'absence').
FP(I,J)	FFIRE		The relative proportion of age class J in site class I that is burnt in any year.
FSALV	MANAGE		The proportion of the area that is burnt in any year, above which salvaging operations will take place.
GHA(I,J)	VOLUME		The annual growth per ha of age class J in site class I (after Plonski 1974).
GMIN	MAXVOL		The minimum annual growth rate of the

Variable	Program segment	Values	Description
			age class - site class combinations still remaining to be harvested ((IH>3). GMIN can be <0.
H	MAIN		The fraction of age class J in site class I that is lost to fire.
	HARV		The volume, or area, of age class J in site class I that is harvested.
HMIN	MANAGE		Minimum volume per ha for harvesting.
HSALV(K)	MAIN		The volume of burnt wood that can be salvaged K years after it is burnt. (K<5; K=5 is not used at present).
IA(I)	TABLE		Integer version of SA(I).
IAF	PFIRE	1 or 2	= 1 if the proportion of the total area that is burnt each year is constant; = 2 if that proportion is variable with a Weibull distribution.
IAV	MANAGE	1 or 2	= 1 if the annual harvest is regulated by area; = 2 if the annual harvest is regulated by volume.
IC	MAIN	1,2 or 3	Number of site classes.
ICLASS	MAIN		Number of years in each age class in the printed age-class distribution tables.
IFR	PFIRE	1 or 2	= 1 if the relative proportion of the area that is burnt in an age class is constant; = 2 if that proportion is dependent on age and site class.
II	MAXVOL		The site class of the next age class to be selected for harvesting (IH>3).
IINT	MAIN		The interval, in years, between printing age-class distribution tables.

Variable	Program segment	Values	Description
IND	MAIN	1,2 or 3	Indicates the type of age-class distribution in the initial forest. [IND(I) equals I in subroutine TABLE].
INFIL	MAIN	< 20 ch	Name of file (UNIT=9) on which initial forest data are stored (IND=3).
IOUT(K)	MAIN		An array used solely for converting real variables to integers for output (K<13).
ISALV	MANAGE	< 5	Length of the salvage period in years.
ISEED	MAIN		A random number seed (<2147483647).
IV	VOLUME	1,2 or 3	Indicates the yield function that is used.
IV(I)	TABLE		Integer version of SV(I).
JCLASS	MAIN		Number of years in each age class in the plotted age-class distribution histograms.
JINT	MAIN		The interval, in years, between plotting age-class distribution histograms.
JJ	MAXVOL		The next age class selected for harvesting.
JOUT(K)	MAIN		An array used solely for converting real variables to integers for output (K<13).
KINT	MAIN		The interval, in years, at which summary results are written on file FORMOD.OUT for subsequent listing on a printer.
MAGE(I)	MAIN	< 225	Highest one-year age class in site class I in the initial forest (IND=1 or 2).
MAX	TABLE		The oldest one-year age class present in the forest.

Variable	Program segment	Values	Description
MHA(I)	MANAGE		Rotation age for site class I (IH=2 or 3).
MHO(I)	MANAGE		Age at which overmature stands are harvested in site class I (IH=2 or3).
MINA	MANAGE		Minimum stand age for harvesting (IH>3).
NPER	MAIN		Period number (length of period = KINT years).
NYR	MAIN		Number of years for which the test will be run.
P(I,J)	HARV		Proportion of age class J in site class I that will be harvested.
PF	PFIRE		The fixed proportion of the area that is burnt each year (IAF=1).
PSALV	MANAGE		Proportion of burnt wood that can be salvaged (IH>3).
S	VOLUME	1,2 or 3	Site class.
SA(I)	TABLE		The total area for site class I. [SA is undimensioned in subroutine PLOTAC].
SALVA	MAIN		Area of salvaged wood.
SV(I)	TABLE		Total volume for site class I. [SV is undimensioned in MAIN].
TEST	MAIN	< 9 ch	Test No. (printed at the top of each page of output).
TITLE	MAIN	< 46 ch	Title for test.
V(I,J)	MAIN		Volume of age class J in site class I.
VC	HARV		= V(II,JJ) adjusted by the compliance factor, COMPF (IH>3).
VCUT	MAIN		Total volume of harvested wood.
VFLOSS	MAIN		Volume of burnt wood.

Variable	Program segment	Values	Description
VFSALV	MAIN		Volume of burnt wood that is salvageable (VFSALV=VFLOSS*PSALV).
VGROW	MAIN		Gross annual growth (see Appendix I for details).
VH	MAIN		The area, or volume, of age class J in site class I that is lost to fire.
VHA(I,J)	VOLUME		Volume per ha of age class J in site class I (after Plonski 1974).
VHARV	MAIN		Initially, and in subroutine HARV, VHARV is the total harvest volume. Later, the volume of salvaged wood is deducted and VCUT becomes the total volume harvested.
VIJ	HARV		= V(II,JJ): the volume of the next age class - site class combination selected for harvesting (IH>3).
VLO	MANAGE		The prescribed lower limit for the volume to be harvested in any year (IH>3).
VMAX	MAXVOL		The maximum volume per ha among the site class - age class combinations still remaining to be harvested (IH>3).
VRES	MAIN		Total volume of the forest at the end of the year.
VSALV	MAIN		Volume of salvaged wood that is harvested.
VTOT	MAIN		Total volume of the forest at the beginning of the year.
VUP	MANAGE		The prescribed upper limit for the volume to be to be harvested in any year (IH>3).
WB	PFIRE	> 0	The 'scale' parameter of the Weibull distribution used for annual fire prediction (IAF=2).

Variable	Program segment	Values	Description
WC	PFIRE	> 0	The 'shape' parameter of the Weibull distribution used for annual fire prediction (IAF=2).
X	MAIN		The percentage of the area lost to fire.
YES	MAIN		= 'Y'.
YNF	PFIRE	Y or N	= 'Y' if a file, FPFIRE.PLT (UNIT=1), is to be created to plot fire/stand age probability curves.
YNH	MANAGE	Y or N	= 'Y' if if a proportion of the burnt wood is to be salvaged.
YNP	MAIN	Y or N	= 'Y' if files, AGECLA.PLT (UNIT=1), and SHIST.DAT (UNIT=12), are to be created to plot age-class distribution histograms.
YNR	MAIN	Y or N	= 'Y' if a file, FORRES.PLT (UNIT=2), is to be created to plot results; = 'N' if plotting is done using SAS/GRAPH (see YSAS).
YNS	MAIN	Y or N	= 'Y' if the final state of the forest is to be saved on file FOREST.DAT (UNIT=1).
YSAS	MAIN	Y or N	= 'Y' if files, SGRAPH.DAT (UNIT=10) and SHIST.DAT (UNIT=12), are to be created for plotting using SAS/GRAPH.
YNT	MAIN	Y or N	= 'Y'if a file, AGECLA.TAB (UNIT=4), is to be created to print age-class distribution tables.
YNY	VOLUME	Y or N	= 'Y' if a file, FYIELD.PLT (UNIT=1), is to be created to plot yield curves.
ZA	HARV		Cumulative area selected for harvesting.
ZV	HARV		Cumulative volume selected for harvesting.